DEPARTMENT OF
AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY.
JNO. E. HOLLINGSWORTH, Commissioner.

THIRD ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY OF TEXAS,

1891.

E. T. DUMBLE, F. G. S. A.,
STATE GEOLOGIST.

AUSTIN:
HENRY HUTCHINGS, STATE PRINTER
1892.

LETTER OF TRANSMITTAL.

OFFICE OF COMMISSIONER OF AGRICULTURE,
INSURANCE, STATISTICS, AND HISTORY,
AUSTIN, TEXAS, May 1, 1892.

Hon. James S. Hogg, Governor of Texas:

DEAR SIR—The Third Annual Report of the Geological and Mineralogical Survey of Texas is herewith submitted according to the requirements of law.

State Geologist E. T. Dumble has had charge of the Survey from the beginning, and the progress made from year to year, as evidenced by the reports, is justly credited to him and his assistants. The year 1891 was rather a remarkable one for the development of the State's wealth and mineral resources, as will appear from an examimation of this report.

The study of lignites, in which Texas abounds, has interested Professor Dumble for some twelve or fourteen years, and the value or utility of the same engrossed much of his time and attention in 1891. During a trip to Europe he made a thorough examination as to the use and value of lignites, which will doubtless prove a great benefit to Texas, for it will go far towards solving the question of cheap fuel, as the tests made since his return demonstrate.

The work being done in that branch of this Department is bringing to light the latent resources of the State in such a way as to convince the most skeptical of the value of the Survey, and it is no longer a question as to whether the Survey shall live, but what the appropriation shall be, and it is hoped the Legislature will act liberally in providing funds for its maintenance.

I have the honor to remain, with much respect and esteem, your obedient servant,

JNO. E. HOLLINGSWORTH,
Commissioner of Agriculture, Insurance, Statistics, and History.

FINANCIAL STATEMENT.

Appropriation for the Geological Survey of Texas, January 1, 1891, to December 31, 1891.

Balance unexpended December 31, 1890		$8,340 68
Appropriation March 1, 1891, to February 28, 1892		35,000 00
Expended:		
Salaries	$21,045 61	
Field equipment	617 43	
Field expenses	6,329 36	
Instruments and apparatus	1,346 19	
Furniture and fittings	700 95	
Books and maps	802 93	
Laboratory supplies	635 77	
Printing and engraving	1,998 40	
Office supplies	417 41	
Incidentals	435 70	
Balance	9,010 93	
	$43,340 68	$43,340 68

Appropriation for traveling and other expenses of an investigation into the Utilization of Lignite.

Amount of appropriation	$3,000 00
Amount expended	1,553 75
Balance	$1,446 25

LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY,
GEOLOGICAL SURVEY OF TEXAS,
AUSTIN, TEXAS, May 1, 1892.

Hon. J. E. Hollingsworth, Commissioner of Agriculture, Insurance, Statistics, and History, Austin, Texas:

DEAR SIR—I have the honor to transmit herewith the Third Annual Report of the Geological and Mineralogical Survey of Texas.

This report contains, as far as we have been able to prepare them, the results of the work of the Survey for the year 1891. Much material, however, still remains on hand for study, and until proper determinations on it are secured final conclusions cannot be drawn in regard to many points of interest and value. Some of the determinations depend on an increase of library facilities, and others on our opportunity and ability to secure the work of specialists in certain departments of scientific work—difficulties which can only be overcome gradually.

Please accept my hearty thanks for your kindness, consideration and assistance during the progress of the work.

Yours very truly,

E. T. DUMBLE,
State Geologist.

CONTENTS.

REPORT OF STATE GEOLOGIST.

REPORTS OF GEOLOGISTS.

ACCOMPANYING PAPERS.

HOUSTON COUNTY, BY W. KENNEDY.

NOTES ON THE GEOLOGY OF THE COUNTRY WEST OF THE PLAINS.

TRANS-PECOS TEXAS, BY W. H. VON STREERUWITZ.

ILLUSTRATIONS.

ERRATA.

Page 205, foot note: For "Silliman," read "American."
Page 271, line 24: Omit "Wanting."

GEOLOGICAL SURVEY OF TEXAS.

REPORT OF THE STATE GEOLOGIST

FOR

1891.

DEPARTMENT OF AGRICULTURE INSURANCE, STATISTICS AND HISTORY
GEOLOGICAL SURVEY OF TEXAS
E. T. DUMBLE, STATE GEOLOGIST.
PROGRESS MAP
Scale of Miles.
1891
Steinwitz,
Comstock,
Cummins, + + + +
Walker, —·—·—·—
Taff, xxxxxxxx
Kennedy,
GULF OF MEXICO
NEW MEXICO
INDIAN TERRITORY
TEXAS
ARK.
PUBLIC LAND
JULIUS BIEN & CO. LITH. N.Y.

THIRD
ANNUAL REPORT
OF THE
GEOLOGICAL SURVEY OF TEXAS.

E. T. DUMBLE, State Geologist.

INTRODUCTORY.

In accordance with the original plans of the Survey, while keeping steadily in view the economic features, the first year of each biennial term is devoted mainly to stratigraphical geology. Therefore the report of the work which has been done in the year just closing will deal largely with the details and descriptions of the character and extent of the rock material of the different formations over which we have worked, although many very important facts regarding the resources of the regions will also be presented for the first time.

WORK OF THE THIRD YEAR.

TOPOGRAPHY.

The lack of accurate maps, which has been a great disadvantage to the Survey since its commencement, is being supplied as rapidly as possible by the work of the United States Geological Survey, the United States Coast and Geodetic Survey, and by our own field parties. There is, however, very much yet to be done in this direction, owing to the great area covered by the State; and several portions of Texas, of which it is necessary to know the accurate topography before certain important geological questions can be satisfactorily settled, lie outside the present limits in which the United States Surveys are able to work, and are too large a task to be undertaken by this Survey under the present appropriations. For this reason general conclusions must sometimes be made on data which are not as complete as they should be, and in consequence the details, when determined, may prove the real conditions to be somewhat different from our present understanding of

them. Every season adds its increasing increment, however, and it is believed that the work now being carried on by the United States Geological Survey in three different portions of the State, by the United States Coast and Geodetic Survey on the Rio Grande border, together with such work as our own field parties can accomplish, will in a short while give us the means for all such determinations.

CO-OPERATION OF THE UNITED STATES GEOLOGICAL SURVEY.

The following report of the work done by the United States Geological Survey during the year 1891 was kindly furnished by Mr. R. U. Goode:

The appropriation bill for the United States Geological Survey for the fiscal year ending June 30, 1892, provided that the amount appropriated for topography should be expended in equal parts, one-half east and one-half west of the 100th meridian.

Thus for topographical purposes there are two general branches, separated by the 100th meridian and independent of each other — the eastern under Mr. Henry Gannett, and the western under Professor A. H. Thompson.

According to this division of the United States, Texas is apportioned in approximately equal parts to the two topographic branches as above described.

For administrative purposes these branches are divided into various divisions, the divisions again subdivided into sections, and in turn a section may consist of several parties.

In this way the eastern part of Texas is attached to the Central Division of the Eastern Branch, and the portion west of the 100th meridian constitutes the Texas Division of Western Branch of Topography.

The Central Division is under Mr. John H. Renshawe, Geographer, and the Texas Division is under Mr. R. U. Goode, Geographer. In the former division there was a small amount of work done in Texas by a party temporarily detailed from Arkansas Section under Mr. George T. Hawkins, Topographer. This work consisted in running several careful lines along various railroads in Cherokee, Smith, Anderson, Houston, Angelina and Nacogdoches counties.

These lines were connected with the astronomical station of the United States Coast and Geodetic Survey at Jacksonville, were checked by numerous observations for azimuth, and when completed served the pur-

pose of furnishing control—that is, fixing position on earth's surface—of three atlas sheets in that vicinity, a portion of two of which was mapped in 1889.

The Texas Division as organized during the past field season was divided into two sections:

1. The Eastern Section, which consisted of four parties, as follows:

(a) Topographical party No. 1, under H. S. Wallace, Topographer, with E. McL. Long as assistant.

(b) Topographical party No. 2, under R. O. Gordon, Topographer, with Charles B. Green as assistant.

(c) Triangulation party under Charles F. Urquhart, Topographer, with Jeff. D. Reagan as assistant.

(d) Level party, under Perry Fuller, Assistant Topographer, with R. B. Robertson as rodman.

2. The Trans-Pecos Section, which consisted of two parties:

(a) Topographical party under W. H. Herron, Topographer, with John McConn as assistant, and

(b) Triangulation party under R. U. Goode, Geographer, with Joseph Jacobs as assistant.

The triangulation party in Trans-Pecos Section was only in field about a month, having in that time completed triangulation sufficient to control the four sheets forming the square degree 31°–32° and 105°–106°, after which the party was disbanded, Mr. Jacobs reporting to Mr. Herron as an additional assistant, and Mr. Goode resuming his executive duties.

The parties of Texas Division as above organized were in the field from the latter part of May until the first week in November, during which time four sheets—Roby, Sweetwater, Fort McKavett, Rock Springs, and a portion of a fifth, Brackettville, were mapped, all being adjacent to and immediately west of the 100th meridian, and comprising parts of the following counties:

Stonewall, Fisher, Nolan, Coke, Schleicher, Sutton, Edwards and Kinney.

All of the work done in Trans-Pecos Texas was in El Paso county and consists of the sheets Sierra Blanca and Sierra Prieta, these being full sheets and forming the eastern half of the square degree 31°–32° and 105°–106°, and El Paso, Fort Hancock and Rio Grande sheets,

which are fractional, the Rio Grande crossing them and dividing their area between the United States and Mexico.

At the end of the general field season in November, when the majority of the force proceeded to Washington, D. C., for office work, a small party under E. McL. Long, Assistant Topographer, with Jeff. D. Reagan as assistant, was organized and continued in the field for the purpose of completing Brackettville sheet and surveying sheet immediately north, which work will be completed sometime in the spring.

The El Paso sheet was surveyed by Mr. Joseph Jacobs in the spring (1891) before the regular parties were organized.

Thus the total output in Texas for the season 1891–92 will consist of six complete sheets near the 100th meridian, and five sheets, two complete and three partial, in Trans-Pecos region, the whole amounting to about 9,720 square miles, as follows:

Roby sheet	1,003 square miles	
Sweetwater sheet	1,008 square miles	
Fort McKavett sheet	1,025 square miles	
Rock Springs sheet	1,030 square miles	
Nueces sheet	1,035 square miles	
Brackettville sheet	1,040 square miles	
Total Eastern Section		6,141 sq. mi.
Sierra Blanca sheet	1,019 square miles	
Sierra Prieta sheet	1,014 square miles	
El Paso sheet	821 square miles	
Fort Hancock sheet	665 square miles	
Rio Grande sheet	60 square miles	
Total Trans-Pecos Section		3,579 sq. mi.
Grand total Texas Division		9,720 sq. mi.

The above together with area surveyed in previous years constitutes forty-eight atlas sheets, covering about fifty thousand square miles of territory, or nearly one-fifth the entire area of Texas.

The scale for the field work on sheets mapped last season was mile and half to one inch, with exception of El Paso sheet, which was worked on the scale of two miles to one inch, and the scale of publication will be 1:125,000, or about two miles to one inch. The contour interval is 25 feet except in such localities where a 50 foot interval was sufficient to show the detailed topography.

In addition to the sheets mentioned in the Second Annual Report, the following have been published:

Dallas, Fort Worth, Cleburne, Weatherford, Palo Pinto, Eastland and Hayrick, and the following have been engraved and are ready to print: Waco, San Angelo, Albany, Eden, Ballinger, Abilene and Anson.

CO-OPERATION OF THE UNITED STATES COAST AND GEODETIC SURVEY.

Captain Stelman Forney, of the United States Coast and Geodetic Survey, had charge of the party at work in the Rio Grande, and he is now engaged in extending the line southward from El Paso toward Presidio.

WORK OF THE STATE SURVEY.

The United States Geological Survey having undertaken the topographic mapping of Trans-Pecos Texas, Professor Streeruwitz was enabled to use his party on some points of special interest in connection with the geology and mineral resources of the region. This included a survey of certain portions of the Carrizo, Diabolo and Quitman mountains, including the Hazel mine and accompanying vein deposits of copper ores.

Dr. Comstock's party, in making the trip from San Angelo southward to Eagle Pass, and from that point to Gillespie county, secured all of the topography possible along their route, connecting their line of levels and transit line with their work of the previous year, both on leaving and returning.

Professor Cummins' party also secured some details of topography along their line of sections around and over the Staked Plains.

GEOLOGY.

In May and June the parties took the field, under instructions which have been faithfully and efficiently carried out, and which have resulted in securing information of greatest value to the State. The work, as outlined in the instructions given, was intended to furnish material for a more specific subdivision of the various formations into terranes, and to assist in the correlation of the deposits as they occurred in different portions of the State, as well as the further determination of the economic possibilities of each terrane as a basis for the work of next year.

One general problem was given each party—the study of water supply, both surface and artesian.

The map accompanying this report gives the general route of each field party.

EAST TEXAS.

The report of Dr. Penrose on the Tertiary deposits of the Gulf Coast gave us the broader characteristics of that formation with admirable clearness, and with such exactness that no great change has been found necessary. It was, however, considered desirable to subdivide the Timber Belt and Fayette beds into such terranes as might be recognizable at this time in order that the horizons of the various clays, lignites, greensand marls, iron ores, etc., might be definitely determined, and time saved in the detailed study of the resources of the formation. This detailed study and subdivision was also very important to enable us to ascertain more positively the conditions of the artesian water supply. In order that there might be no confusion of ideas regarding these horizons, Messrs. Taff, Kennedy and Walker first made an examination of the Cretaceous-Tertiary contact in company, and a brief inspection of the Basal Clays as well. Messrs. Walker and Kennedy then made a trip from Terrell to Tyler, across the Basal Clays to the Timber Belt beds, and then each of the three took up his separate line of section. These sections were made, using the levels of various lines of railroads as a base for obtaining elevations, supplemented by transit lines and lines of levels when necessary. In this way only could we secure sufficiently accurate sections without topographical maps.

Mr. Kennedy was given the eastern and by far the longest line of section. It began at Terrell, in Kaufman county, and followed the line of the Texas and Pacific Railway, via Wills Point to Mineola, the International and Great Northern Railroad via Tyler, Jacksonville, Trinity and Corrigan to Colmesniel, and the Sabine and East Texas Railroad to the Gulf at Sabine Pass.

Mr. Walker's section was west of the Colorado river, taking the line of the Gulf, Colorado and Santa Fe Railroad from Cameron to Galveston as a base.

Mr. Taff began at Corpus Christi and followed the line of the Texas–Mexican Railroad to Laredo, the International and Great Northern Railway to Cotulla; thence west to Carrizo Springs, and up the Nueces and Leona rivers to Uvalde, where he reached the Cretaceous again.

This gives three complete sections across the Tertiary and Quaternary deposits of the Gulf Coast in addition to those already made by Dr. Penrose and myself, and will enable us to differentiate the formations much more closely than has heretofore been possible.

In addition to the work of these sections, Mr. Kennedy made a detailed study of Houston county, and Mr. Walker a similar study of Washington county and various separated localities of interest.

The Basal Clays have been extended by this season's work to cover Tertiary materials lying below the beds first described, thus adding considerably to their thickness. The Timber Belt beds, which are in great part at least of Claiborne age, as determined by their fossil contents, have been more fully studied, but as yet no final divisions are made in them, and it will require detailed study over a wider area before this can be done satisfactorily. This is rendered necessary by the character of the materials, which are largely uncompacted, and the manner of their deposition, which was often in bays or coastal lagoons, as well as by the fact that the present comparatively level surface of the area occupied by them affords few opportunities for sections of any considerable length. It may be found practicable, on further investigation, not only to make such divisions as alternating lignite and iron deposits, but also to combine the upper members of the Timber Belt beds and lower part of the Fayette beds into a division representative of the Oligocene, or Jackson of Alabama.

The character of the Miocene, to which the Fayette beds have been referred, has been studied and many new facts obtained, including several localities of fossil beds containing casts of a bivalve which Dr. W. H. Dall considers to be possibly a *Macoma*. The specimens occurring at the base of the sandstone are, however, very imperfect.

Overlying these Fayette beds, and stretching still further to the north and west, are the deposits of gravel and sand. In places these are mixed with clay, especially in the eastern half of the State, but to the west a calcareous material takes the place of the clay and forms a conglomerate, which caps even the higher Cretaceous hills as far west as Del Rio, and is found in all the canyons making up into the plateau country. In places this calcareous deposit takes the form of beds of limestone, one of which was described by Dr. Penrose under the name Reynosa beds. I have intended the name to cover the entire division. This may also include the Texas representatives of the Orange sands,

or Lafayette formation as it is now known, which have been up to this time classed as Quaternary by us.

The beds which we have classed as Quaternary are the materials corresponding to the Lafayette formation in Eastern Texas and the overlying Coast Clays. Above these come the deposits of the present rivers and gulf coast.

The section of the artesian well at Galveston, which is now over 2400 feet in depth, gives an idea of the thickness of the deposits and of some of the Tertiary as well:

			Total.
Recent		46	
Coastal Clays		269	315
Lafayette formation		143	458
Miocene	Fayette Sands	830	1288
	Fayette Clays	587	1875
Eocene		550	2425

The fossils found at 2300 feet are those of Burleson shell bluff, which is practically in the direct line of dip from Galveston, distant 140 miles, with a difference in elevation not exceeding 350 feet, which would give these beds the average dip of 18 feet per mile.

In this area the wide spread character of the lignite beds has been clearly demonstrated, new and valuable deposits of iron ores located, the position of many valuable beds of clays, diatomaceous earth, green-sand marls and building stones determined, and the salt deposits have been more clearly defined and described.

The artesian water conditions are found to be favorable over a large district, but the wide spread character of the gravel and accompanying sands of the southwestern portion of the State prevented our getting the necessary information in that region to enable us to speak positively as to the likelihood of flowing wells, as we had hoped to do.

The character of the soils of this area, with a few exceptions in East Texas, has not been properly appreciated. Many of them are of excellent quality, and by proper drainage and cultivation will yield large returns to agriculture. They are now being studied in the laboratory, preparatory to a classification according to their origin and present qualities.

The greensands have had special attention. Where they have been tried by farmers they have fully borne out all the claims which have

SILVER FALLS, CROSBY CO.

been made for them by the Survey. Thus practical agriculture again proves the value of chemical analysis as a basis for restoring the fertility of the soil.

CENTRAL AND WEST TEXAS.

To secure definite information regarding the country west of the 100th meridian, two sections were made, both starting from the vicinity of San Angelo. Dr. Comstock and party made a close instrumental section southward, through Schleicher, Sutton, Val Verde, Kinney and Maverick counties, to the Rio Grande; thence northward, through Uvalde, Edwards, Bandera, Kerr and Gillespie, connecting again with his work of last year.

Professor Cummins followed the Cretaceous escarpment west from San Angelo until he reached the Staked Plains. After some local studies, he took his party northward along the foot of the Plains to the line of the Fort Worth and Denver Railroad. Turning westward he crossed over into New Mexico, and after examinations of the geology of certain sections, turned south and followed the valley of the Pecos river to Pecos City, having thus completely circled the Staked Plains.

The object of these sections, as stated in my letters of instructions, were:

A more accurate knowledge of the condition of the northern scarp of the Cretaceous table land and its relations to the underlying formations; stratigraphy of the Cretaceous, and manner of disappearance northward under the Plains formation; geology, agriculture, grazing, forest and water conditions of the Staked Plains; character of the Cretaceous table land with its general geology, agricultural, grazing and water conditions; the extension of the Silurian geanticlinal southwest, and its relation to the Cretaceous north and south of its manifestation; the stratigraphy of the southwestern Cretaceous, and the determination of the probable thickening of that formation toward the south and west; the character and effect of the basaltic eruptions, the presence or absence of beds of the Upper Cretaceous superimposed on those of the Lower in the table land; mineral resources and artesian water conditions of this region.

This work gives a connected section from the Canadian river to the Rio Grande, and the results furnish us a volume of information concerning the general geology, and in regard to the water supply and other conditions of this hitherto little known region.

In addition to this I made a detailed section along the Rio Grande, from Del Rio to Eagle Pass, in the greater part of which I had the assistance of Mr. J. Owen.

From Uvalde Mr. Taff took up the study of the Cretaceous, tracing the partings of the limestone and Ponderosa marl from that point to Austin.

By the work we have done the boundary of the Staked Plains is described, and its topographic features clearly stated. The strata covering the surface are all found to be of later Tertiary age, certainly not earlier than the Loup Fork beds, and probably Pleistocene in part. These beds thicken toward the northwest, and at the northern scarp of the Plains rest directly upon rocks of Triassic age. The Triassic rocks underlie the Plains material as far south as the thirty-third degree of latitude, or a little lower, beyond which point a thin series of the Cretaceous rocks, thickening towards the south, appears between the Triassic and Blanco Canyon beds.

On the western side of the Plains the erosion of the Pecos river has cut through the Plains material and underlying formations to its present channel. The determination of the Cretaceous age of the Tucumcari beds, and that these beds are higher in that system than the Caprina limestone, and occur without any recognizable beds of the Fredericksburg, or older Cretaceous, below them, is of considerable scientific value. The same fact was observed along the entire western side of the Plains. The age of the deposits as here given are fully proven by the fossils obtained from them.

South of the Staked Plains lies an elevated Cretaceous table land, rising from the surrounding country both on the north and south by a steep escarpment. The rocks of this plateau are of Lower Cretaceous age, and passing from east to west its lower beds are in contact successively with those of Cambrian, Silurian, Carboniferous, Permian and Triassic age. Passing south to the Rio Grande, successively higher Cretaceous beds are encountered, thickening rapidly and overlapping like shingles upon a roof. The same relations are apparent in higher beds down the Rio Grande from Del Rio to Eagle Pass. The presence of a pre-Cretaceous fold, which has had a marked influence upon the deposits of that age and upon the subsequent topography and drainage of the State, is determined, as well as the fact that the later basaltic

outflows have frequently used the lines of weakness in the trend of the disturbance which formed the fold.

The topographic features of the plateau have been studied, and the difference due to different geologic structure in the river system of the plateau and those lying north of the fold clearly shown.

Much information regarding the basaltic outflow was obtained, but is not yet thoroughly worked out. The present indications are, that they began towards the west, during the Lower Cretaceous period, and continued in operation until the middle of the Upper Cretaceous, possibly extending gradually eastward or northeastward during the time.

Between Del Rio and Eagle Pass—or more properly speaking, Webb Bluff, some forty miles below that city—we have a section of the Upper Cretaceous series which is somewhat different in character from that of the Central Texas area. The Fish beds of the latter are here represented by the Val Verde Flags, a series of limy flags and clays having a thickness of some six hundred feet. The overlying Pinto limestones, which compare in every way with the Austin limestone, are also much more strongly developed, and give a section of some fifteen hundred feet. But the greatest difference is to be observed in the beds which overlie these. Their development is so great that I have placed them in a separate division, and called it the Eagle Pass Division. The two lower members of the division, the Upson clays and San Miguel sands, are represented in the Central Texas section by the Blue or Ponderosa marl and the Navarro or Glauconitic beds, respectively, as fully determined by the fossils found in them; but so far nothing corresponding to the Coal series and Escondido beds (Marine Cretaceous), which overlie these on the Rio Grande, have been recognized in the Colorado section. The total thickness of the different beds is over five thousand feet, if the average dip of one hundred feet per mile, which has been proved above Eagle Pass, holds good for the portion of the section below that point. Proceeding southeast toward the Gulf we find these beds directly overlaid by deposits of Eocene and later age.

The water supply of the Plains was fully investigated, and it was found that although there is no hope of obtaining artesian water, except in rare instances, the supply to be had in wells is practically unlimited. These wells vary in depth from twenty feet to three hundred feet, according to localities. The springs and streams find their supply from the same source as that of the wells. West of the Plains water is easily

obtained in shallow wells, while along the Pecos, on the eastern side of the Guadalupe mountains, the supply is abundant, and in places artesian flows can be secured. The only minerals of the Plains are the gypsum and salt. The soils are of great fertility, and the rainfall, although not so abundant as it is further east, is nevertheless fully sufficient to mature good crops in most seasons, for the reason that it falls during the time at which it can be of most service—in the summer.

Perhaps one of the most useful results of the season's work is the demonstration of the agricultural capacity of the Plateau region in which the valley soils, which cover a large area in the aggregate, are not only excellently adapted for tillage, but are so situated that they can be irrigated in many places from the abundant supply of water that was found to exist at no great depth below the surface, "which appears to be a vast body of underground water lying like an overflowing lake beneath this great divide." The great value of the determination of this immense water supply underlying the Staked Plains and the Plateau, which is accessible by wells over so wide an area, and breaks out in bold and never-failing springs in so many places, is so self-evident that words could not enhance it.

The more barren highlands are well adapted for sheep raising, while the pecan growth of the southward flowing river valleys is of such extent and character as to furnish the basis for a great industry in itself.

The mineral resources of the plateau are confined to ochres, kaolin, lime and cement materials and building stones.

The principal economic materials of the Cretaceous region south of the plateau are the coal, asphaltum, clays and artesian water. The Eagle Pass coal basin has been described previously. The northern outcrop of the coal seam has now been traced and mapped, and its relations to the underlying and overlying materials studied in such a manner that they can be used as indicators of its presence and its approximate depth at any given point, or its entire absence.

The asphaltum deposits which were described by Mr. Owen in the First Report of Progress, have been examined, first by the party under Dr. Comstock and afterward more in detail by Mr. F. S. Ellsworth, and my first statements regarding their character and value verified and enlarged. They are much more extensive than has previously been suspected.

CENTRAL CRETACEOUS AREA.

Having completed his work on the Tertiary section, I gave Mr. Taff the study of a strip of Cretaceous, beginning at the Carboniferous-Cretaceous contact in Lampasas county, crossing the formation to the Cretaceous-Tertiary contact in Williamson county. This had for its object a clearer definition of our Cretaceous in a typical section, and especially the relation of the stratigraphical and economic conditions of the formation.

From the study of widely separated sections some complications had arisen and an uncertainty as to the relations of certain beds of the formation. A very careful study was, therefore, made of the lower beds from Red River to Austin and the exact relationship determined. This work, as will be seen from the paper accompanying this report, developed the fact that the Alternating beds of our Colorado section, as previously published, are in fact an integral part of the Trinity sands of the same section, and are overlaid by a second series or continuation of the same sands, the Paluxy. Its extent and character warrant the giving to it of a divisional name, and we have therefore called it the Bosque Division, and include in it the Trinity sands, Alternating beds and Paluxy beds.

The work on the Lampasas-Williamson section was also of great value stratigraphically. Horizons not previously observed in this section were found and studied, and in many cases their exact areal extent within the section mapped. The artesian water conditions were determined and the results appear in the accompanying report. The results are such as will make the further study of the Cretaceous and its resources much simpler than it has been.

TRANS-PECOS TEXAS.

In this district, through the work of Professor W. H. Streeruwitz and his party, the rocks of Carboniferous age, which had been previously described, have been traced and mapped over a large area; the age and relations of certain conglomerates, which have been a disturbing element in the study of the region, have been decided; the exact stratigraphic relationship between the schists and the red grit has been determined, through sections fortunately laid open by the torrential rain storm which occurred in the latter part of the summer. Some fossils have been secured, which, although badly preserved, will, it is

hoped, give an idea as to their geologic age. The extent of the crystalline schists, which near Eagle Flat are associated with strongly metamorphosed cherty limestones, true marbles, etc., is found to be much greater than was suspected. This is the series of rocks which I suggested in the First Annual Report were probably the equivalents of the Texas system of the Central Mineral District.

Minerals.—The ore-bearing character of the Carrizo mountains is fully proved—magnetic iron, copper and lead ores, with silver and gold, having been found, and good results shown wherever prospecting has been done. The Hazel mine was carefully studied, as being the best developed property in the district, and the report contains a description showing the amount and character of work which has been done in it. The production has already exceeded $60,000 although very little stoping has been done. The fine marbles of this range will some day attract the attention they so richly deserve.

Water Supply.—The first requisite to the proper development of Trans-Pecos Texas is an adequate and constant water supply. Professor Streeruwitz, in every report he has made, from the beginning of the Survey, has urged this matter strenuously, showing that wells or streams could not be depended on, and that the storage of water in reservoirs was the only practical way of accomplishing this end. He also shows that the character of the topography and the rock formation is such that there are many places at which storage reservoirs could be built at moderate cost, which would be suitably located for irrigating large bodies of very fertile lands, or for use in mining operations, or for the raising of stock. His own observations, as well as those of the government observers at Fort Davis and Fort Bliss, prove that the annual rainfall is sufficient to give an adequate supply for all these purposes if it is properly cared for. The greatest obstacle to be overcome is the fact of the larger part of the lands being sectionized, and the alternating sections belonging to the State and railroads respectively, so that no one could get a sufficient amount of land in a body to warrant the expenditure necessary for building a dam.

During my visit to his camp in the Diabolo mountains, last summer, this matter was one of the most constant discussion, and it finally occurred to me that there might be a possibility of the inauguration of this work by the State, provided locations could be found which would be entirely on the State lands, and that it would be possible to utilize

convict labor in building the dams and in the necessary preparations for irrigation. The State, in its various branches of University, Public School, Asylum and unoccupied lands, is most largely interested in this section. These lands are practically valueless in their present waterless condition, whereas, with such a supply of water as can be secured by this means they can be made to "blossom as the rose," and made to support a large population and remunerate the State a thousand fold for the outlay necessary for their reclamation.

Upon my return to Austin the matter was referred to the Commissioner, Mr. Hollingsworth, and Governor Hogg, and instructions were given us to ascertain whether suitable localities could be found affecting only State lands.

Some difficulty was experienced in locating such corners as would show that the land was all undoubtedly public land, but there are places, without doubt, in the region northeast of Van Horn, which will afford suitable localities for such reservoirs.

Major Powell, Director of the United States Geological Survey, has promised not only to designate such localities as may be found by the topographic parties at work in the district, but also to estimate cubical contents, height of dam and other details, thereby greatly facilitating our work.

THE GALVESTON ARTESIAN WELL.

The city of Galveston having decided to bore an artesian well to a depth of three thousand feet, I considered it of highest importance to secure an accurate record of the boring with specimens of all the materials penetrated. I therefore commissioned Mr. J. A. Singley to watch the progress of the well and take specimens of the materials as they came out together with all the fossils he could secure. During the entire boring he was present night and day, taking specimens every few feet, or as often as the materials changed. By this means we have secured as exact a record as is possible from a well sunk by this system, and the information obtained will be of great value in the work of the Survey. The well was not completed at the close of the year, but from an examination of the fossils found in the lower stratum we ascertained that they were in beds belonging to the Eocene or Lower Tertiary and that, judging from our section on the Brazos river, it would not be very far to the Cretaceous rocks. The observations will be continued until the completion of the well.

LIGNITE INVESTIGATION.

In consequence of my previous investigations and reports on this subject and the urgent need for a cheaper fuel for the development of manufactures in a large portion of the State, an appropriation was made at the regular session of the Twenty-second Legislature "to examine and test the quality and value and best method of utilizing the various kinds of lignite in this State."

In pursuance of this law, under the instructions of Hon. Jno. E. Hollingsworth, Commissioner of Insurance, Statistics and History, I went to Europe and examined the various deposits of lignite or browncoal and the processes by which they were utilized.

At the International Congress of Geologists held in Washington, D. C., in August, I met many European geologists who gave me much information and assistance in this work.

During my stay in Germany I made Halle, a. S. my headquarters, that being the center of the greatest browncoal deposit of Germany. From this point I visited the various mines and factories of the province of Saxony, and also those of the Rhine provinces. In Austria I visited the mines and factories of Styria and Bohemia. I was everywhere accorded the fullest opportunity for securing the information of which I was in search, and which could only have been gotten by just such personal examination as I made, and could not by any possible means have been secured by correspondence in so detailed and exact a degree.

The general facts as submitted in my preliminary report are again given herewith.

EUROPEAN BROWNCOAL.

The browncoal of Europe may be divided into four general classes, viz: 1, Lignite; 2, Common Browncoal; 3, Pech Coal; 4, Glance Coal—all of which have representatives in Texas.

LIGNITE.

In Germany and Austria this term is only used to designate such fossil fuel as fully retains its woody character and fiber. It is usually found accompanying other varieties of browncoal, and consists of those fragments of the original woody material from which the beds were formed that have escaped maceration and decomposition. In some places, however, when conditions were favorable to its preservation it forms the main body of the deposit. Sometimes it occurs

surrounded by earthy browncoal, and often has particles of fatty browncoal or jet inclosed with it, following the rings of growth. Much of it as it comes from the mine retains its form and character so completely as to be almost indistinguishable from the ordinary wood of the present time, except that it is somewhat darker in color.

COMMON BROWNCOAL.

This name covers a number of varieties, varying in color from yellow to brownish black, and from those having a specific gravity less than water to those of 1.2 and 1.3. Their common qualities are their large percentage of water and their earthy, friable nature. The two most important of these varieties are "Schweelkohl" and Earthy Browncoal.

SCHWEELCOAL.—This variety, in its purest form, resembles a yellow clay much more closely than it does coal. Its composition and character, as revealed by chemical analysis and the microscope, vary somewhat from the other browncoals, and it is the variety which has the least specific gravity. It is the richest in tarry matter, and is therefore especially desirable for the manufacture of paraffine and oils. It occurs most frequently with earthy browncoal and often in alternating layers with that variety.

EARTHY BROWNCOAL.—This variety of browncoal is, as its name indicates, of an earthy character, brown to brownish black in color, in its ordinary condition containing as much as forty-five or even fifty per cent of moisture. While it somewhat resembles our Texas browncoal, especially in the fatty streaks which occur in it, the German is much more friable than ours and also much inferior to it in heating value in the raw state on account of the great percentage of water it contains. This is the character of browncoal that is found most largely developed in the district around Halle, a. S., and in the Rhine provinces. Much of it lies very near the surface, in beds varying from a few inches to sixty feet in thickness, and is most often mixed with Schweelcoal to a greater or less extent. From this variety of browncoal is manufactured the "nass-press-stein" and browncoal briquettes without bond.

PECH COAL.

A darker and firmer variety of browncoal, which contains a smaller amount of water, and which often closely resembles pitch both in color and fracture, is called Pech coal. The coal of the Bohemian basins is

very largely a mixture of common browncoal (of somewhat drier nature than the German) and Pech coal, together with some lignite, and is the equivalent of the larger part of our Texas deposits.

GLANCE COAL.

This is the finest variety of lignitic or browncoal, in certain instances passing into jet. It occurs principally in Styria with other varieties of browncoal, although smaller quantities occur in many localities.

These varieties are again subdivided into minor divisions, and they pass by insensible gradations one into the other, frequently in one and the same bed.

STATISTICS.

The following statistics, taken from the government reports of the empires of Germany and Austria, show to what extent these browncoals were used during the year 1890:

	Tons mined.	Value at mine.
Germany	15,468,434	$9,967,812 00
Austria	15,329,056	12,482,603 00
Total	30,697,490	$22,450,415 00
Of which—		
Rhine Provinces	661,590	$381,139 00
Halle, a. S.	14,077,382	9,031,238 00
Styria	2,270,023	2,942,327 00
Bohemia	12,190,932	8,240,780 00

This amount, over three hundred thousand car loads, is nearly thirty per cent of the entire coal (stone coal and browncoal) production of these empires, which was (for 1890) 104,702,370 tons. Of the total amount of browncoal mined, the district around Halle, Germany, and Bohemia and Styria, in Austria, produced eighty per cent.

The amount of brown coal used in the manufacture of briquettes, coal bricks, tar, paraffine, etc., during the year was a little less than seven million tons, and the remainder—over twenty-three million tons—was used "raw," or just as it came from the mine, without preparation of any kind.

USES OF EUROPEAN BROWNCOAL.

As has already been stated in our circular No. 8 and in the various reports of this Survey, the uses of browncoal are as varied, general and

important as those of stone coal. The results of my personal investigations not only fully confirm the statements made heretofore by myself and other members of the Survey, in regard to the availability of the Texas browncoal for fuel purposes, but add greatly to them.

LIGNITE.

When lignite is found in sufficient quantity, it is charred in meilers, kilns or retorts, in the same manner as ordinary wood, and yields a charcoal of similar quality, and equally suitable for all fuel purposes. Thus, in lower Styria, where it occurs in great quantities as a part of a browncoal deposit, having a total thickness of over three hundred feet, it is charred in ovens arranged for the recovery of the by-products as well as the charcoal. The charcoal made here is used in iron smelting.

Where the lignite occurs in smaller quantities, as in the province of Saxony and on the Rhine, it is used with the browncoals under steam boilers and for various other fuel purposes.

COMMON BROWNCOAL.

The Schweelcoal, as has already been stated, contains large amounts of tarry matter, and for this reason is especially desired by the Schweeleries or factories, which manufacture from it the tar and its derivatives, paraffine and oils of various grades. These oils vary in quality from one especially adapted for the manufacture of gas for lighting purposes, through heavy and light oils to a solar oil about equivalent to our best refined petroleum. While the introduction of American and Russian petroleum into Germany has in some measure checked the working of the Schweeleries for oil purposes, the demand for paraffine is so great as to keep the factories still at full work. This industry, as shown by the statistics given, is one of great importance to these districts of Germany, amounting as it does to over four millions of dollars annually and giving employment to several thousand men. The records of the German Browncoal Association show that in the year 1890 the amount of browncoal used by the companies belonging to the association for the manufacture of tar and paraffine was over twenty millions hectolitres, and the value of the product seventeen million one hundred and twenty thousand marks ($4,280,000). The coke made from the Schweelcoal by this process is called "grude coke," and experience has proved it to be such an excellent fuel for household purposes that the demand is in excess of the supply. It is used

in stoves of special construction for cooking and heating. It is of too fine a grain and not compact enough to be of any use in smelting iron.

The earthy browncoal is used "raw," or as it is mined, for household, manufacturing, or steam purposes, and is also manufactured into nass-press-stein and briquettes.

Nass-press-stein, or coal bricks, are made by mixing the browncoal with water until it is of a putty-like consistency, compressing by machinery similar to that used in making pressed brick, and then drying these brick in the air. While the amount of this fuel is small in comparison with that of briquettes made by the dry method, it is nevertheless a useful and serviceable fuel for household purposes.

Dry briquettes, made from this variety of browncoal, are in great demand, and the output is increasing yearly. The process of manufacture consists of drying the browncoal by one of the several methods until the water contained in it is reduced to a certain percentage and then compressing it under a pressure equal to that of fifteen hundred to two thousand atmospheres. The resulting briquette is of a lozenge or elliptical shape, some six inches in length and about one inch in thickness, very firm and durable. The compression is so perfect that the briquette will not absorb water even if it be laid in it for some time. The earthy browncoal is preferred for briquette making on account of the ease with which it is pulverized.

In a raw state browncoal is also used for burning bricks, stoneware, and drain tile, for which purposes it is preferred to any other fuel. Brick clays and fire clays are often found in close proximity to the browncoal, and the manufacture of bricks, fire brick and tiles, at an extremely low price, is thus rendered practicable, and a great number of mines have brick yards in connection with them by means of which they are enabled to make use of all their coal, even what would otherwise be refuse.

At one of the larger brick works on the Rhine the experience of several years trial proved that a firing with a mixture of browncoal briquettes and raw browncoal gave better results in actual work than stone coal alone, stone coal with briquettes, or stone coal and raw browncoal, and at the time of my visit works were just being completed for briquetting their browncoal for use in this manner.

In using this earthy browncoal for such firing purposes, or under steam boilers and elsewhere, due attention is given to the arrangement

of the fire-boxes and grates to suit the fuel. If a flat grate is used the grate bars are made very narrow and with small intervals between each. The favorite grate, however, is called the "treppen rost," and is a grate arranged in a series of steps by which the air gets proper access to the browncoal without need of a blast sufficient to carry away the smaller particles unburned.

For household purposes stoves of suitable construction for cooking and heating, using raw browncoal or briquettes as fuel, are for sale everywhere in Germany. The briquettes are preferred for fuel on account of their cleanliness and freedom from smoke in burning.

The comparative extent of the use of the various fuels in the ordinary way may be seen from the statistics of the fuel supply of the city of Berlin for the year 1890, taken from the annual report of the Kohlenzeitung:

Stone coal, coke, etc.		1,755,383 tons
Bohemian browncoal	242,027 tons	
German browncoal briquettes	577,674 tons	
German browncoal	21,534 tons	
Total browncoal		841,235 tons

or about thirty-one per cent of the entire fuel supply.

A great many tests have been made to determine the ratio of fuel value of the German browncoal and stone coal. The results give the ratio between the Westphalian coal and earthy browncoal and briquettes about the following relation in amounts required to produce the same amount of steam:

Westphalian Coal.	German Browncoal.	Briquettes.
1	2 to 2½	1¼ to 1½

The Bohemian browncoal contains less moisture than the common browncoal of Germany, and is therefore a better fuel in its raw state. Throughout Bohemia it is put to every use—domestic, manufacturing or metallurgical—for which stone coal is used, except the smelting of iron ores and production of pig iron. The locomotives, which have very heavy work over the mountain railways, use it exclusively. Brick works, chemical works, glass factories, firebrick and tile works, potteries, cement factories and limekilns are all run successfully and economically with this browncoal as their only fuel. It is used as fuel *exclusively* by the largest iron and steel works of the country for the

processes of converting pig iron into wrought iron and steel and for rolling this into rails, bars, wire, sheet iron and all similar products.

The use of this fuel in this manner was made possible by a close technical study of its character and a practical application of the results to manufacturing purposes. The construction of the fireboxes and grates is such that the necessary conditions to its best utilization are fulfilled, and when high heats are wanted for smelting iron or heating ingots, as in the manufacture of wrought iron and steel and in rolling mill work generally, gas firing is resorted to.

This kind of firing, which is the one most generally in use with the browncoal for all purposes where the higher temperatures are required, has several different methods of application, varying with the purpose for which the heat is required, but all having the same general principle at the foundation.

The browncoal is first converted into gas by burning in a producer of some description, usually a rectangular firebox with treppen rost grate, fed from above. The gases produced in burning are carried off by proper conduits, the tarry matters separated, in part at least, by passing through an hydraulic main, and the remaining fixed gases pass either directly to the furnace or more often through a Siemens regenerative furnace to the place where they are burned. Here they are mixed with heated air, and the heat produced by the combustion is ample for any and all purposes for which it may be required. The Bohemian browncoal has also been successfully briquetted after the German or dry method already mentioned, and a factory has been in operation for several years at Koenigsberg, near Carlsbad.

This coal has also been coked by several methods, but up to the present time the coke has not been brought into use as fuel. In some places this was prevented by the character of the coke itself, which was unsuited for blast furnace purposes. In other cases, when the coke was suitable for such use, the cost of producing it was so great that it could not successfully compete with the cheap Silesian coke from stone coal.

In Styria there is found a still drier browncoal, which in places very closely resembles jet. It is probably the equivalent of our Laredo coal, except that it contains very much less ash. This browncoal is of excellent quality, and has also been coked by methods similar to those used with the Bohemian, but the coke is not in use at present for the same reasons given above. It has, however, been found not only practicable

but economical to use *thirty per cent and upward of this raw coal* in connection with coke from stone coal in the blast furnace for smelting iron ore, and there are iron furnaces which have been in operation for years using this character of fuel.

This browncoal, mixed with a lignitic coal, is used in the same vicinity for rolling mills, steel and wrought iron production, etc. The browncoal of Bohemia and Styria is also used in the manufacture of gas for lighting purposes. It is distilled in retorts of the usual form, and the operation differs in nowise from that with ordinary bituminous coal, except that the heated air from the furnace is used to evaporate the surplus moisture from the raw browncoal before it is put in the retort. The gas coke made from the browncoal in Bohemia is sold for use in the zinc works.

In Styria a browncoal similar to that of Texas is briquetted with a bond of stone coal pitch. Only the smalls are used, because there is usually a demand for all the lump coal that can be mined throughout this whole region, and the briquette industry is therefore not needed. The briquettes are, notwithstanding, sold at a price fully equal to that of stone coal. The system used is the Coufinhal, and the briquettes are like those now in the Museum of the Survey, which were made during my earlier experiments.

From these facts it will be seen that the browncoals of Germany and Austria are not only adapted for use as fuel for all purposes, but that they are so used, and used successfully. Moreover, the statistics show conclusively that the browncoal industry of Germany and Austria is one of very great magnitude, and it will be shown by a comparison of statistics for twenty or thirty years past that the increase in the production of browncoal has kept fully abreast of that of stone coal.

COMPARISON OF EUROPEAN AND TEXAS LIGNITES.

As stated in the beginning of this Report, I have compared our Texas lignites with those of Germany and Austria, and find that we have representatives of the various classes mentioned. I have personally examined the various classes of browncoal as they occur in the deposits, as they come from the mine, and as they are used in their various applications, and I have compared them with our Texas lignites, both in their physical character and chemical composition, with the result as stated. I have submitted average specimens of our

Texas browncoals to the highest authorities on this subject in Germany and Austria, and they, without exception, confirm my statement, and unite in pronouncing the Texas browncoals of excellent quality, fully equal to the Bohemian, and equally suitable for use for all domestic, industrial and metallurgical purposes. I have therefore the pleasure of reiterating the statement made several times already, and each time supported by stronger evidence, that Texas has in the immense deposits of browncoal a cheap fuel which can be used for every purpose for which fuel is needed.

It should, however, be plainly understood in the beginning, that the browncoals of Texas will be found to differ very widely in quality, and it will require analyses of each deposit to tell with certainty for what purpose it is best adapted. Deposits will be found containing too large a percentage of ash, and some perhaps too large a percentage of sulphur, to be of value as fuel, although other uses may be found for them. Those that are suited for briquetting without bond may not serve equally well for other purposes, and some of the varieties of browncoal will not form a briquette at all by the dry method.

It is impossible, with detached basins of browncoal, formed under somewhat diverse conditions and stretching across an area seven hundred miles in length, that all should be equally good. That there is an abundance of the material that is of a most excellent quality is shown by the examinations and analyses already made by the Survey of deposits and specimens from all portions of the lignite belt, and yet other of these analyses also prove the existence of deposits which are comparatively worthless.

Therefore, in any undertaking having browncoal as its basis of supply, either as fuel or raw material for manufacturing purposes, an accurate knowledge of the material should be obtained before operations are begun.

UTILIZATION OF TEXAS BROWNCOAL.

The fact of the great fuel value of the browncoal having been thus fully decided, I have endeavored to secure all possible information, and when practicable the detailed drawings or plans of the various kinds of ovens, fireboxes, grates and appliances for using browncoal. Some of these are the subjects of patents, and can therefore only be used under royalty or purchase; others, and some of these the most important, are not patented and are free to all.

Through the kindness of the owners of the iron works and rolling

mills in Bohemia and Styria, I have secured plans in detail of the fireboxes, gas producers, and arrangements by means of which they use the raw browncoal for the purposes stated. I have also the plan of the blast furnaces which are now in operation using a mixed fuel of coke and raw browncoal.

From the manufacturers of locomotives I have detailed plans of the fireboxes used on such locomotives as are intended for browncoal. All of these plans and methods are applicable for the use of our Texas browncoal for similar purposes.

The machinery for the production of briquettes by the dry method is manufactured in Germany, the most of it under patents. General descriptions and estimates of the cost of erection are in the office.

Presses and machinery for the production of briquettes using pitch as a bond are manufactured in Germany, France and England. I have plans and estimates of the different styles and sizes of these showing approximate cost of erection and operation.

Plants for the production of tar, paraffine, oils, etc., from the browncoals are of a much more complex nature. General plans and estimates are now in the office, and details will be furnished me as soon as they can be prepared.

Some of the principal uses of our browncoal will undoubtedly be in the manufacture of brick, firebrick, drain tile, paving tile, stoneware, pottery, glassware, cement and lime. Plans for the construction of ovens especially designed for these purposes, and in successful use in Germany with browncoal firing, are also being prepared.

All of these are at the service of those interested in the subject.

It can be stated now from experiments and analyses already made, both by private individuals and by the Survey, that we know that we have in the Texas browncoals certain varieties that are rich in tarry matter which will serve as a source of paraffine, and that some varieties can be briquetted with pitch as a bond and others by the dry method.

Special examinations and tests of our Texas browncoal by the largest browncoal manufacturing establishment in Europe, by the various methods of briquette manufacture in Germany and France, and by other specialists are now in progress, and as soon as their final reports are received the results will be published, together with the details of the various plants, estimates of the cost of erection, operation, etc.

PALEONTOLOGY.

The assistance afforded us by specialists in this branch of geology during the second year of the work of the Survey was not only continued but greatly increased during the year that has just closed. In this, as in our topographic work, we are under renewed obligations to the United States Geological Survey.

In reply to a request for their assistance in this line of work, I received a letter from the Director, promising full co-operation, and in the work of the whole year the promptness of the determinations and replies to inquiries by every member of the Survey with whom we have had correspondence have been of greatest value to us.

The materials sent were fossils of various kinds, the identification of which were necessary for the correct determination of the geological age of the beds from which they were taken, but in some instances more detailed work was necessary.

The collections made by Professor Cummins, during the field season of 1890, contained a large number of new Nautiloid forms, and they were sent to Professor Alpheus Hyatt for study and description. His report, with illustrations and descriptions of the new forms, taken together with that accompanying the Second Annual Report, contains a far larger number of species than have been gotten together in any publication previously.

A number of specimens of fossil plants which were taken by Professor Cummins from the Permian rocks of North Texas were sent to Dr. I. C. White, of Morgantown, W. Va., who identified them, and presented the results of his work in a paper before the Geological Society of America, at the meeting at Columbus, in December. The results are of great interest, proving as they do the distribution of Permian plants of the same varieties from Pennsylvania and West Virginia to Texas.

The vertebrate fossils collected by Professor Cummins were sent to Professor E. D. Cope for determination. They were found to be of considerable interest, and a paper on them by Professor Cope accompanies this report.

Dr. W. P. Clarke, of Johns-Hopkins University, who is making a special investigation of the Echinodermata, has studied the forms taken from the Cretaceous of Texas, identifying about twenty species,

several of which are new. Descriptions of a number of these were published in the Johns-Hopkins University circulars.

The collection of fossils which has been sent to Dr. Roemer embraced a number of forms from the Lower Cretaceous. He was at work on them during my visit to Breslau in October, but his death in December left the work uncompleted.

The sub-fossils found by Prof. Cummins on the western side of the Staked Plains were submitted to Dr. Sterki and his report will be found in its place among the accompanying papers.

CHEMICAL LABORATORY.

Mr. J. H. Herndon was in charge of the chemical laboratory until May 6th, when his services were discontinued and Mr. Magnenat given charge. Mr. Magnenat was without assistance until after my return to Austin in November, when I appointed Mr. Goodall H. Wooten as assistant. These gentlemen have carried on the entire work of the laboratory, a general statement of which will be found in another place in this report.

Immediately upon the organization of the Geological Survey, I issued Circular No. 1, dated October, 1888, giving a statement of the law concerning the analyses of ores and materials of supposed economic value, and the terms on which they would be made by the Survey for those who desired such analyses for personal or private use. This was never intended to be applied to analyses of such a character as were of direct interest to the Survey ; but as there seems to be a misunderstanding as to its exact meaning, it may be best to explain the practice of the Survey in this matter.

The plain intention of the law organizing the Survey was the benefit of the people of Texas—to establish a place where citizens could send any material occurring on their property, and secure an intelligent estimate of its value at the least possible outlay. This does not mean a laboratory for the purpose of making money or competing for patronage with the professional analytical chemists and assayers of the State.

In the rules which I established for the guidance of the laboratory work I took all this in consideration, and divided the work on such material as was sent in by persons not connected with the Survey into two general classes.

The first class comprised all materials, the examination of which could only be for the personal benefit of the party sending them in. This comprised suspected ores, minerals and certain other material.

The second class, on the other hand, comprised such materials as could not by their nature be of benefit to the sender alone, but which must, if of value at all, affect a larger or smallei number of persons.

For the first class the following general rules were adopted:

On receipt of any material whatever, such an examination shall be made of it as will determine its character and possible value. This may, under some circumstances, extend so far as assays for silver and gold, or even a complete quantitative analysis. When this is completed, the sender is notified of the general character of the material without giving details; and if it appears of value, Circular No. 1 is inclosed giving the conditions and the law under which analyses are made by the Survey, and when complied with and the fee paid, the examination is made, and detailed results are furnished the sender under the seal of the department.

All such assays or analyses, for which a fee is taken, are the exclusive property of the person for whom they are made, and are not used by the Survey without permission of the owner.

For materials of the second class, which in general refers to minerals of such widespread character as prevents any one person from reaping the exclusive benefit of our examinations, the same rule holds. A careful preliminary examination is made (which often includes a complete quantitative analysis) and a general statement is given the sender as before. If he wishes a complete analysis, the law must first be complied with, and then the payment of the fee makes the analysis private property.

In addition to this, many matters of interest come to light through correspondence, and in order to settle some points, specimens are often collected under my suggestion and direction, by some obliging and public spirited citizen, and sent me for investigation. I usually give the collector a general statement of the results, but in no such case do I furnish him the detailed analysis.

To summarize:

All specimens received have such an examination made of them as is in our judgment necessary to determine their probable value.

If the examination is paid for by the party sending the specimen in,

the analysis becomes his private property, and is not used by the Survey without permission.

If the examination is not paid for, the analysis is the property of the State, and can be used as occasion requires.

All commercial analyses are referred to such professional analytical chemists and assayers as have sent us their addresses, and we endeavor to confine our work, as closely as possible, to matters bearing directly or indirectly upon the purposes of the Survey, as we have outlined them in our publications.

The following circular regarding water analyses was rendered necessary by the press of work and number of such analyses offered from different portions of the State:

GEOLOGICAL SURVEY OF TEXAS.

ANALYSES OF WATERS.

Circular No. 9.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS AND HISTORY,
AUSTIN, TEXAS, August 1, 1891.

The requests for analyses of waters of various kinds have become so frequent that it is impossible for the Survey to make them with the present chemical force. We have therefore adopted the rules of the Experiment Station of California with some modifications.

A close discrimination will be made between cases of merely individual interest and those affecting a larger circle or the public at large.

Of the latter class of cases, those involving irrigation water and the water supply of towns or cities are of such wide importance that the Survey will undertake to carry the analyses to the limit required by the objects in view.

The waters of artesian wells, forming outlets of extended artesian reservoirs, which may be still further tapped and used for irrigation or household purposes, manifestly fall within the same category.

Of the above classes of water, therefore, both "qualitative" and "quantitative" analyses, sufficiently detailed for all practical purposes, will be made upon request as rapidly as they can be reached upon the regular docket.

The waters of private wells and springs, interesting only the owners, will, as a rule, be analyzed "qualitatively" only, so far as to determine their healthfulness or adaptation for domestic use; except that in all cases the total quantity of solid ingredients and the proportion of earthy and saline (permanently soluble) matters will be determined. These determinations will, as a rule, be amply sufficient to decide whether or not such waters are suitable for the uses contemplated, and, if faulty, to determine the means, if any, for improving their quality. Waters suspected of sewerage contamination will also be investigated with respect to their contents of improper ingredients of animal origin.

The analysis of supposed medicinal waters will, as a rule, be carried only so

far as to determine if they are likely to prove of value, so that the sender may decide whether or not it may be worth while to go farther and incur the expense of a detailed quantitative analysis for commercial purposes. The Survey does not undertake the latter class of work under any ordinary circumstances.

MODE OF TAKING SAMPLES.—Since the value of any analysis is essentially dependent upon the correct sampling of the material, the following directions should be carefully observed when waters are sent for examination:

1. Not less than two wine bottles of the water should be sent in any case. An ample supply of material not only greatly facilitates the chemist's work, but also enables him to control at once, by repetition, any unexpected or questionable result he may have obtained.

2. Of irrigation or any other waters intended for quantitative analysis, at least two gallons should be sent in every case. Such samples should be put up in new, or very carefully cleansed, demijohns, and not in earthenware jugs, and least of all in tin or other metalic cans. In both of the latter class of vessels the water is almost sure to be so contaminated before arrival as to render the samples useless. Demijohns, and bottles as well, should be rinsed with sand or fine gravel (not with bird shot) until it is absolutely certain that nothing adheres to the inside, and until all odor of previous contents (vinegar, wine, molasses, whisky, etc.), has been removed. The corks used for closing should also be new, or, if used before, should be boiled with water until fully cleansed of all odors or adherent deposits

3. The water should in all cases be taken directly from the well or spring when bottled. If gas escapes with the water, a sample of the gas should be collected in a bottle first filled with the water and then inverted in the spring basin so as to allow the gas to bubble into and fill the bottle, which should then be immediately corked under water, the cork promptly dried and then (after cutting down to the level of the bottle neck) carefully covered with sealing-wax, or beeswax, if the former be not available.

4. All samples should be accompanied with a full statement of the location of the source of the water, of the depth of well, amount of water or flow of spring or stream; as far as possible of the nature of the rock or other material from which the water comes, and of all other facts bearing upon its nature and possible origin. In case of warm springs the temperature should also be given.

All such packages should be forwarded by express, charges prepaid.

E. T. DUMBLE,
State Geologist.

LIBRARY.

The need of library facilities becomes greater every day, and I have added as many books as possible during the year just closing by purchase and exchange. The acquisition by exchange of reports of State and Government Surveys, both in this country and in Europe, is aiding us materially in this direction.

MUSEUM.

The arrangement and classification of the museum is now in progress. A number of new cases have been added, and while the room designed for museum purposes is not large enough to make a complete display of the collections of the Survey, typical collections can be shown which will not only be of interest to the observer and of great educational value, but at the same time impress upon all who see them the fact of our varied mineral and agricultural wealth.

During this year we have added to the great number of ores, rocks, minerals and fossils of the geological collections proper, a series of birds and birds' eggs of North Texas, collected by Mr. G. H. Ragsdale, and a similar series of those from the coast country, collected by Mr. J. A. Singley during the intervals of work in the Galveston deep well, which he has been watching.

Mr. Singley has also made collections of the land, freshwater and Gulf shells of Texas, which are arranged in the cases in connection with a loan collection from him of foreign shells.

CO-OPERATION WITH THE PUBLIC HIGH SCHOOLS.

In continuation of the plans described in the Second Annual Report I have had a large amount of material collected for the purpose of supplying the Public High Schools of the State with collections of typical specimens of rock materials, ores and fossils representing the geology of Texas, for the purpose of assisting them in the study of geology and mineralogy. We have now on hand sufficient material to supply every High School in the State, but the press of work in other directions and the small force at my disposal have prevented the preparation of the collections as rapidly as I wished. The collections sent out embraced only rocks and minerals. The collection of fossils made for the purpose will be arranged as soon as possible.

During the year the following schools were supplied:

Sulphur Springs High School, Professor B. R. Morrison, Principal.
Gordonsville High School, Professor B. F. Holcomb, Principal.
Mexia High School, Professor R. B. Cousins, Principal.
Blanco High School, Professor W. H. Bruce, Principal.
Elgin High School, Professor W. H. Stevenson, Principal.
Eddy High School, Mrs. Bedichek, Principal.
Van Alstyne High School, Professor H. L. Piner, Principal.
North Texas Female College, Sherman, Mrs. L. A. Kidd, Principal.

Lockhart High School, Professor J. E. Cook, Principal.
Gonzales High School, Professor Oscar Chrisman, Principal.
Shelbyville High School, Professor M. M. Dupre, Principal.
Navasota High School, Professor S. H. Flake, Principal.
Austin College, Sherman, Professor S. C. Scott, Principal.
Sherman Institute, Mrs. M. L. Nash, Lady Principal.
Vernon High School, Professor T. S. Cox, Principal.
Prairie View State Normal, Prairie View, Texas, Professor Anderson, President.
Paul Quinn College, Waco, Professor N. A. Banks, President.
Whitesboro High School, Professor J. M. Stewart, Principal.
Baylor Female College, Belton, Texas.
Garden Valley High School, Professor T. J. McBride, Principal.
Post Oak Island High School, Miss L. V. Jones, Principal.

OFFICE WORK.

The volume of office work expands greatly with each succeeding year. As the work of the Survey becomes better known to the citizens of our own State and all who are in any way interested in it, the number who seek information and assistance from us steadily increases. While this fact entails more work and longer hours, it is at the same time most gratifying, since it is the highest possible assurance of the appreciation of our work by the people whom it is intended to benefit.

The administration work must necessarily remain in my own hands. This in itself requires so much time in planning the work and directing the operations of the field parties, in overseeing the correspondence, editorial work, the laboratory, museum and library, that very little is left me for any original work.

The first portion of the past year was spent in the preparation of the Second Annual Report, the publication of which was delayed from various causes until July 1st.

The edition consisted of three thousand copies, two thousand five hundred of which were issued bound in one volume, and five hundred as separate articles.

I then spent several weeks visiting the different field parties until I received instructions to take up the lignite investigation, which trip occupied my time until November 16th. Since my return I have been in the office.

Mr. A. C. Gray was given charge of the office in June. He supervised the issuing of the Second Annual Report, and with the assistance of Mr. W. S. Hunt carried on the general office work during my absence in Europe.

As an index of the amount of work involved in correspondence alone, the number of letters received during the year was more than two thousand, and a still larger number were written.

PUBLICATIONS.

The publications of the year 1891 by the Survey are as follows:

I. Second Annual Report of the Geological Survey of Texas. 8vo. pp. cx., 738; pl. xxviii.

Of this Report the following parts were issued as separates:

Report of the State Geologist.

Reports on the Iron Ore District of East Texas.

Report on the Geology of Northwest Texas.

Report on the Geology and Mineral Resources of the Central Mineral Region of Texas.

Report on the Geology and Mineral Resources of Trans-Pecos Texas.

Carboniferous Cephalopoda.

II. Preliminary Report on the Utilization of Lignites.

Of the total number of each publication the law requires that a certain number be retained by the Secretary of State, and the remainder are turned over to this department for distribution. After reserving a small number for future needs and the required number for our exchange list, the balance are distributed to all citizens of the State who wish them, on payment of postage or express charges.

ACKNOWLEDGMENTS.

Our field parties have met with ready assistance and help from the citizens of the various portions of the State in which the work has been carried on. The number of persons who have thus aided us, and to whom our thanks are due, is so great that I can only acknowledge our obligations to them collectively, and trust that sooner or later they may be more fully repaid by the results springing from our labors.

To the United States Geological Survey we are under renewed obligations for a more extended co-operation even than that of previous years. To the United States Coast and Geodetic Survey our thanks are also due for their continued assistance, as they are also to the many Paleontologists who have aided us as I have already described.

To the members of the Survey, one and all, who have given such faithful work toward the carrying out of the plans outlined for them, I return my most sincere thanks.

GEOLOGICAL SURVEY OF TEXAS.

REPORTS OF GEOLOGISTS

1891.

REPORT OF MR. W. H. VON STREERUWITZ.

INTRODUCTION.

AUSTIN, TEXAS, January, 1892.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—In obedience to your instructions, I took the field in West Texas, May 15, 1891, to proceed with the topography of Trans-Pecos Texas, and to study the geological and particularly the economical features of this part of the State.

I organized my party with Mr. Ralph Wyschetzki and Konrad Girsewald as assistants, securing the other necessary help in the only way possible to engage it in the west—the first best men willing to take employment. To engage cook or drivers in the east would not only be too expensive on account of traveling expenses, but inexperienced eastern men, with few exceptions, are not of much use in the unsettled extreme west, where familiarity with camp life, knowledge of the country, and aptitude and willingness to undergo hardships of any kind are the principal conditions of usefulness.

Having met Mr. Goode, of the United States Geological Survey, with two topographical parties in the field to work up the country between the 31st and 32d degrees of latitude, and 105th and 106th degrees of longitude, I took advantage of this, stopped the topographical parties inside of these boundaries, and commenced to work up the mineral district of the Carrizo mountains and southern part of the Sierra Diabolo, with the Hazel mine and numerous outcrops and indications and a few prospects on silver-bearing copper ores. I mapped part of the country, and took a number of sections which will materially assist in the determination of the very extensive field of the crystalline schists and their relation to the plutonic and volcanic eruptive rocks, as well as of the superimposed sedimentary strata.

I could not effect an extension of the sections to the Guadalupe range, and thus eventually connect them with the mountains north of the 32d degree of latitude, since my wagons and animals, which had been in service under very trying circumstances since the beginning of the Survey, had become worn out to such an extent that I dared only risk short trips, and could not go far from the railroad on account of the scarcity of water.

I therefore reconnoitered the Wiley mountains, and later the northern portion of the Van Horn mountains. After placing the animals (three horses and two mules) with the wrecks of the water and baggage wagon and a well-worn ambulance (the relic left by Mr. Tarr in Toyah) with the camp outfit at Phinney's ranch, disbanded the party and started on with Mr. Wyschetzki and Girsewald for Austin, on the fourth of October.

I regard it my pleasant duty to express to these two gentlemen my sincere thanks for their unremitting zeal in topographical and other work, and for their ever cheerful endurance of hardships under the most trying circumstances.

Respectfully,

W. H. von Streeruwitz.

REPORT OF MR. THEO. B. COMSTOCK.

Austin, Texas, December 31, 1891.

Hon. E. T. Dumble, State Geologist, Austin, Texas:

Sir—I have the honor to report that the field season of 1891, extending from May 25th to September 1st, was given by myself and party to the examination of the region south and southwest of San Angelo as far as the Rio Grande at Del Rio and Eagle Pass, and northward and northwestward from Eagle Pass to a connection with my previous work in the Central Mineral Region. The district covered this year was very large, the lack of water and of food for stock being also a serious hindrance. The problems encountered were mostly of a different type from those of the complicated region to the east of this tract, but they are of such a nature as to render careful work a necessity. However, as the topographic field parties of the United States Geological Survey were at the time engaged in mapping the area, our work was confined to a somewhat narrow belt bordering the lines run for geologic sections.

The field party of 1891, was organized as below:

Theo. B. Comstock, in charge.

R. A. Thompson, topographer.

F. S. Ellsworth, aid.

Meade Goodloe, rodman.

J. C. Hubbard, rodman.

J. E. Whitley, cook.

H. L. Warren, hostler.

The only change in this personnel was the withdrawal of H. L. Warren at Del Rio, early in July. All the other members remained to the end of the season and each performed his duty with credit and satisfaction.

During my absence in June and again in August, Mr. Thompson was left in charge of the field party. In the field, as topographer and as leader of the corps, as well as in the office work of plotting, he exhibited excellent traits and is deserving of especial mention for his

zeal, efficiency and the accuracy with which his observations and computations have been made.

Mr. Ellsworth proved himself invaluable in varied services as confidential assistant, and I take pleasure in bearing testimony to his energy and faithfulness in the performance of many difficult tasks. After my departure he was entrusted with important work, the performance of which has clearly proven his unusual skill as a collector and his ability to manage well in the field. In the office he did excellent work in arranging and labeling collections and in testing rocks, ores, etc., under my direction.

The other members of the party bore unflinchingly hardships of no small moment, and those who continued to the end proved in every way faithful to their trusts, contributing in large degree to the successful accomplishment of the survey in hand.

Your own constant aid and encouragement, as in other seasons, enabled us to overcome numerous obstacles and made possible much that could not have otherwise been undertaken.

Very respectfully,

THEO. B. COMSTOCK,

Geologist for Central Texas.

REPORT OF MR. W. F. CUMMINS.

AUSTIN, TEXAS, November 15, 1891.

Prof. E. T. Dumble, State Geologist:

DEAR SIR--The work done by myself and party during the last seasons' field work was to trace the Carboniferous formation to its farthest outcrop in Central Texas, and to determine the northern extension of the Cretaceous strata along the eastern escarpment of the Staked Plains, as well as to trace and determine the extent of the Dockum and Blanco Canyon beds and their relation to the underlying strata.

A very important question for the northwestern part of the State was to determine whether or not artesian water could be obtained on the Staked Plains. It was already known that the upper strata of the Plains had a general dip from the northwest to the southeast, and it was thought that there might be an underlying strata, whose upturned edge at the base of the mountain range west of the Plains, would furnish a water-bearing stratum that could be penetrated by deep boring farther to the eastward in the country east of the Pecos river. In order to determine this matter, we traveled entirely around the Staked Plains in Texas and New Mexico, and as nearly as could be done during our hasty march, determined the geological age of the strata between the

foot of the mountains on the west and the western escarpment of the Plains. The results of the investigation and determinations are given in a detailed report.

The economic possibilities of the country traveled over have been given particular attention, and as much data as possible has been collected in relation to the fertility of the soil, annual rainfall and the temperature, and especial attention has been given to the subject of irrigation along the Pecos river and elsewhere in my district

The personnel of the party during the entire field work was as follows:

W. F. Cummins, geologist in charge.

N. F. Drake, topographer and assistant geologist.

Duncan H. Cummins, assistant geologist.

R. M. Lynch, rodman.

C. A. Bullion, cook.

W. L. Black, hostler.

We left Austin on the 12th day of May and traveled along the old Austin and San Saba road to the latter place. From thence passing Brady to a point on the San Saba river about sixteen miles east of the town of Menardville. At this place we found the most southern outcrop of the Carboniferous formation in the central area of Texas, it being overlain to the southward and westward by the Cretaceous beds. At this place we began and ran a line of levels, and made a continuous section of the strata westward, passing Menardville and San Angelo, to Big Springs, a distance of about one hundred miles.

From Big Springs we went westward about forty miles, then northwestward to the Sulphur Springs, and from thence southward to Marienfeld, and eastward back to Big Springs.

Again leaving Big Springs, we went northward, tracing the eastern escarpment of the Staked Plains through the counties of Borden, Garza, Crosby, Dickens, Motley, Briscoe, Hall and Donley, to the town of Clarendon, on the line of the Fort Worth and Denver Railroad.

From there we turned westward, and having explored the Palo Duro canyon to the falls, we turned northward to Amarillo, and passing that town continued northward to the valley of the Canadian river, where we reached the old government road traveled by Professor Jules Marcou in 1853, he being the first geologist who ever passed through this part of the country. Turning westward along that old line of travel, we passed through Potter and Oldham counties, crossed the State line and continued along that old route as far as Tucumcari, in New Mexico, a distance of about seventy-five miles west of the west line of the State of Texas. While in the vicinity of Tucumcari we collected a great number of fossils from the beds in that vicinity, the age of which has been a matter of dispute ever since Professor Marcou said they were Jurassic,

in 1853. We will no doubt be able to throw additional light on the subject, based upon the material collected by us during our visit.

Finding it impossible to see the underlying strata by traveling along the western line of the State southward, where we would have been on the high plains and sandhills all the way, we turned directly southward from Tucumcari along the old Fort Sumner road, and after traveling about seventy-five miles reached the Pecos river a few miles above the old fort.

We continued down the Pecos river a distance of about eighty miles to Roswell, and about eighty-five miles further to Eddy, and fifteen miles to the mouth of Black river.

From thence we traveled westward up Black river to its source in the Guadalupe mountains. Then we turned eastward to the head of Delaware creek, and thence to Pecos City, in Reeves county.

From there we continued down the Pecos river to the falls at Horsehead crossing, and passing through the counties of Crane, Upton, Irion and Tom Green to San Angelo, and by the most practicable route to Austin, where the party arrived on the first of November.

This brief summary of the route traveled is not intended to specify all the traveling done by the party, for in many places we made side trips of from twenty to fifty miles. To the faithfulness of the men in their various positions am I indebted for the success of the expedition, and which rendered it possible to make such a trip with so little delay, and collect the large amount of material that we have done with the facilities at our disposal.

The amount of transportation at our disposal was not sufficient to enable us to travel with that ease and expedition we would have liked. During a great deal of the time our teams had to subsist entirely upon grass, and part of the time that was very poor both in quantity and quality. The consequence is, with heavy loads and scarcity of provender, our animals arrived in Austin in a very much jaded and broken down condition.

We have this year done a great deal of work that was merely reconnoissance, and have traveled over large areas of country that had never been visited by even an exploring party of geologists, and many questions relating to the geological age of districts have been determined which heretofore were entirely unknown.

With esteem and respect,

W. F. Cummins,

Geologist for Northern Texas.

REPORT OF MR. W. KENNEDY.

AUSTIN, TEXAS, January 1, 1892.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—The work assigned to me for the season of 1891, as detailed in your letter of April 25th, 1891, is as follows: "The making of a detailed section across the post-Cretaceous deposits, from Terrell, in Kaufman county, via Mineola, Tyler, Lufkin, Corrigan and Colmesneil, to the Gulf."

In accordance with these instructions I left Austin on the 14th day of May for Terrell, and on arrival there began work as soon as the necessary outfit could be gathered.

On leaving Terrell the party consisted of myself, Mr. J. B. Walker, Assistant Geologist, and W. S. Teague, as driver and cook; and on our arrival at Mineola Mr. Walker returned to Austin, preparatory to making a line of sections from Cameron southward, and Teague was discharged at his own request.

While in Mineola I visited and examined the Alba Coal Mining Company's property, and afterwards proceeded to Marshall to dispose of an outfit left there at the close of last season's work.

The driver's place was filled by W. M. Bankston, and I then proceeded to Tyler. While there I was joined by Mr. Frank Fitch, as a volunteer. We then went south to Ashcraft, where Mr. Fitch left and returned home, and I proceeded alone to Rusk. At Rusk, finding it necessary to have another man, I engaged S. A. Adams as a general assistant, and the party moved southward, without any serious difficulties, to the coast.

On approaching the completion of the section, I received your letter of August 7th, containing instructions to resume county work in Houston, Leon and Robertson counties, as soon as the line of sections was completed. Accordingly, as soon as we reached Beaumont and found it impossible to take the outfit any further south, it was turned across country to Crockett, and I went on alone to Sabine Pass.

The outfit arrived in Crockett on the 2d of October, and the work of surveying that county was commenced and carried on until about the end of November, and as the season was then too far advanced for out of door work, the party was disbanded and the outfit stored preparatory to resuming work in Leon county during the coming season.

While in Houston county the success of the work was greatly facilitated and benefited by the kindly assistance and advice of Senator Page and County Surveyor Broxon, the latter gentleman having accompanied me for a week at a time, thereby enabling me to locate places with much more accuracy than could otherwise have been done.

In conclusion, allow me to thank you for your own advice and assistance during the course of the work, and the other members of my party for their attention to the work in hand and general willingness to carry out every duty assigned to them.

Yours respectfully,

WM. KENNEDY,
Assistant Geologist.

REPORT OF MR. J. A. TAFF.

AUSTIN, TEXAS, December 31, 1891.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—I have the honor to submit herewith an administrative report upon the work given in my charge during the year.

It was necessary that further investigations be made upon the geology of the Trinity, Glen Rose, and Paluxy beds, which compose the Bosque division, in order to better determine their stratigraphic and toxonomic relations to each other. Accordingly I took the field April 15, 1891, and made careful sections across these rocks along the valleys of the Bosque river in Erath, Hamilton and Bosque counties, Brazos river in Parker county, South Fork of Trinity river in Parker county, and the West Fork of Trinity river in Wise county. The work was finished May 8th, 1891, and the results are incorporated in my account of the geology of the Bosque Division. In this connection, credit is due Mr. N. F. Drake and Mr. C. C. McCulloch who worked with the writer upon these rocks in the season 1889.

According to your direction, I with Mr. S. Leverett, as geological assistant, and Mr. J. W. Black as aid, began the study of artesian water conditions of southwest Texas, more especially that portion south of the Southern Pacific Railway. Investigation was taken up along the line of the Mexican National from Corpus Christi to Laredo, beginning May 27th, 1891, thence to Cotulla along the International and Great Northern Railway, and thence up the Nueces and Leona river valleys to Montell, Uvalde county. Vast deposits of post-Tertiary drift, composed of silt, gravel, boulders, and tufaceous lime so obscure the rock which govern flowing wells in a great portion of this region, that satisfactory estimates could not be made for sources of artesian water and depths for flowing wells. Much data was obtained, but, knowing that further investigation is to be carried on in this field in the coming season, it awaits a fuller account than can now be given.

The line of parting between the Upper and Lower Cretaceous was traced from the Nueces river valley to Austin, also a study was made

of the Balcones fault, and its line located almost continuously from the Nueces to the Colorado river valleys. Much valuable data was gleaned from the bassaltic outbreaks which occur associated with the Balcones fault in the Nueces, Leona, Frio, Hondo and Medina river valleys. The information obtained throws light upon the age, character and extent of these eruptions of the Balcones fault. The knowledge obtained upon this work is in readiness to join a complete study of the dynamic and stratigraphic geology of the region.

After completing this work, I began the study of the Cretaceous system north of the Colorado river in a typical area across Lampasas, Burnet and Williamson counties. The results of this work are given in the pages of the report upon this area.

Field work ended November 27th, 1891.

The values accruing from the systematic study and survey, which is now in progress, of the artesian water area alone of this region will be more than the cost of the Geological Survey thrice told.

ACKNOWLEDGMENTS.—Mr. S. Leverett, by his valuable assistance in the field and in the office, has rendered possible an important portion of the report.

Mr. Black, by faithful adherence to his duties, rendered valuable service in the field work.

I wish to add that your encouragement and instructions given me while in the field and in the office, as well as the liberty accorded me in the prosecution of my work as an assistant, has been of very great value, and has made possible whatever of value I have accomplished.

With highest esteem, I am, yours very truly,

J. A. TAFF,
Assistant Geologist.

CHEMICAL DEPARTMENT.

REPORT OF MR. L. E. MAGNENAT.

AUSTIN, TEXAS, February 8, 1892.

Hon. E. T. Dumble, State Geologist :

DEAR SIR—I have the honor to transmit herewith a brief report of the work done in the Chemical Laboratory of the Geological Survey during the period embraced between December 13, 1890, and January 1, 1892. During that time five hundred and fifty-five analyses have been made by Messrs. J. H. Herndon, G. H. Wooten and myself.

Below is a table showing the amount and character of the work performed, not including a large number of qualitative analyses and determinations of minerals of which no official record has been kept:

Assays for gold and silver	210
Assays for copper	17
Assays for lead	26
Assays for zinc	12
Assays for platinum	4
Assays for bismuth	1
Assays for cobalt	1
Assays for uranium	2
Assays for tin	1
Iron ores, unclassified, complete	19
Iron ores, unclassified, partial	10
Hematites, complete	2
Iron ores, concretionary, complete	8
Iron ores, concretionary, partial	2
Iron ores conglomerates, complete	8
Iron ores, conglomerates, partial	4
Iron ores, magnetites, complete	7
Iron ores, ochreous, complete	1
Ochres, complete	3
Maganese ores, complete	2
Granites, complete	6
Porphyries, complete	16
Porphyries, partial	2
Clays, complete	16
Clays, partial	4
Soils, complete	25
Soils, partial	5
Greensands, complete	10
Greensands, partial	28
Lignites	23
Coals	9
Mineral waters complete	12
Miscellaneous analyses, complete	49
Miscellaneous analyses, partial	10
Total	555

Very respectfully,

L. E. MAGNENAT,
Chemist in Charge.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS AND HISTORY.

PAPERS ACCOMPANYING THE ANNUAL REPORT

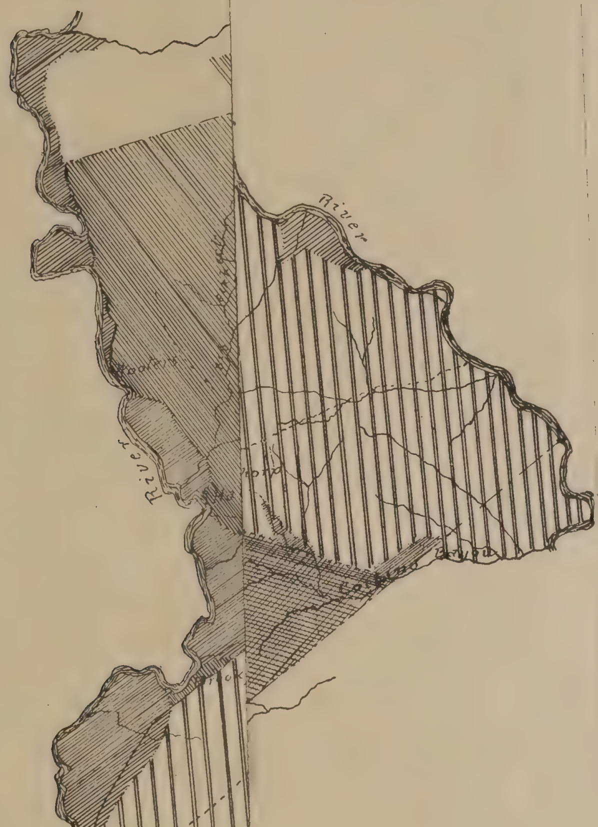
OF THE

GEOLOGICAL SURVEY OF TEXAS,

FOR

1891.

GEOLOGICAL SUPORT, 1891. PLATE II.



MAP OF HOUSTON COUNTY—By W. Kennedy.

HOUSTON COUNTY,

BY

W. KENNEDY.

HOUSTON COUNTY.

BY W. KENNEDY.

INTRODUCTORY.

In the First Annual Report of the Geological Survey of Texas the only reference made to Houston county is a short notice of Cook's mountain (a high hill about two and a half miles west of Crockett), and an outcropping of shell-bearing sand about nine miles northeast of Crockett, on the old San Antonio road.* In the Second Annual Report a more extended reference to the economic geology of this county is made in a preliminary report by Mr. E. T. Dumble, State Geologist,† which is taken for the most part from the notes of Dr. Penrose and the report of Dr. R. H. Loughridge on Cotton Production of the Southern States, Tenth Census, Vol. 5.

The present report is a description of the different features of the geology of the county from the standpoint of a much more detailed examination than has hitherto been made, during which it was ascertained that, in addition to the conglomerate iron ores already described, there are in the county also laminated and carbonate ores, and that the soils can be more properly presented under a different classification than that employed previously.

In order to give the details as completely as desired, it has been found necessary to repeat and enlarge some of the work previously done.

GEOGRAPHY AND TOPOGRAPHY.

Houston county lies immediately south of Anderson, of which indeed, for geological purposes, it might be considered a part. The same beds, so extensively developed in the central and southern portions of Anderson county, extend into and half way across Houston before they are overlaid by the deposits of the newer Tertiary. The eastern boundary of the county is formed by the Neches river, while the Trinity bounds it on the west. Trinity and Walker counties form the southern border. The total area of Houston county comprises eleven hundred and seventy-six square miles.

The surface is generally rolling, and slopes gently towards the south and east. In some places it is broken and hilly to a small extent. The divide between the drainage areas of the Trinity and Neches rivers forms a slightly elevated ridge running in an approximately north and south direction through the center of the county.

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*First Annual Report Geological Survey of Texas, 1889, p. 34.

†Second Annual Report of the Geological Survey of Texas, 1890, p. 318.

The entire surface may be said to be approximately divided into two plains, through which the waters of the larger creeks have cut deep channels, sometimes fringed with broad bottom lands. The northern plain extends across the county in a roughly northeastern and southwestern direction, and has a general elevation of from four hundred and fifty to five hundred and thirty feet, and is approximately co-extensive with the area underlaid by the older Tertiary deposits. The heaviest deposits of Quaternary age also occur in this region.

Throughout the northern plain the streams have a rapid flow, narrow channels with steep banks along the greater portion of their courses, and, except in the immediate vicinity of the rivers, have a very limited extent of bottom lands on either side.

The southern plain occupies the whole of the county from Hurricane bayou southward, and may approximately be considered the area of the newer Tertiary. This plain has an average elevation of about three hundred to three hundred and twenty feet, though some few points rise considerably above this. The streams flowing through this southern plain are sluggish in their flow, and wander tortuously through broad bottom lands, and are almost without exception subject to extensive and deep overflows. Between these two plains there is no apparent break. They graduate into each other through a series of flat topped hills, some of which are covered with ferruginous gravel and sand, and others, such as Cook's mountain, by glauconitic sandstones.

The following table gives approximately the elevations of some of the highest points within the county:

County line of Anderson county	530 feet.
Grapeland	480 feet.
Daley	450 feet.
Augusta	400 feet.
Murchison's prairie	470 feet.
Weches	500 feet.
Stark	385 feet.
Cook's mountain	460 feet.
Crockett court house	370 feet.
Paso	390 feet.
Weldon (Nevill's prairie)	294 feet.
Hyde's bluff	220 feet.
Lovelady	300 feet.
Pennington (Tyler prairie)	300 feet.
Calthorp	300 feet.
Creek	290 feet.
Porter Springs (Mustang prairie)	320 feet.
County line of Trinity county	244 feet.

The most characteristic feature of the topography of the southern portion of the county is the chain of small prairies extending across the southern division, comprising East prairie (an eastern extension of

GENERAL SECTION, HOUSTON COUNTY.

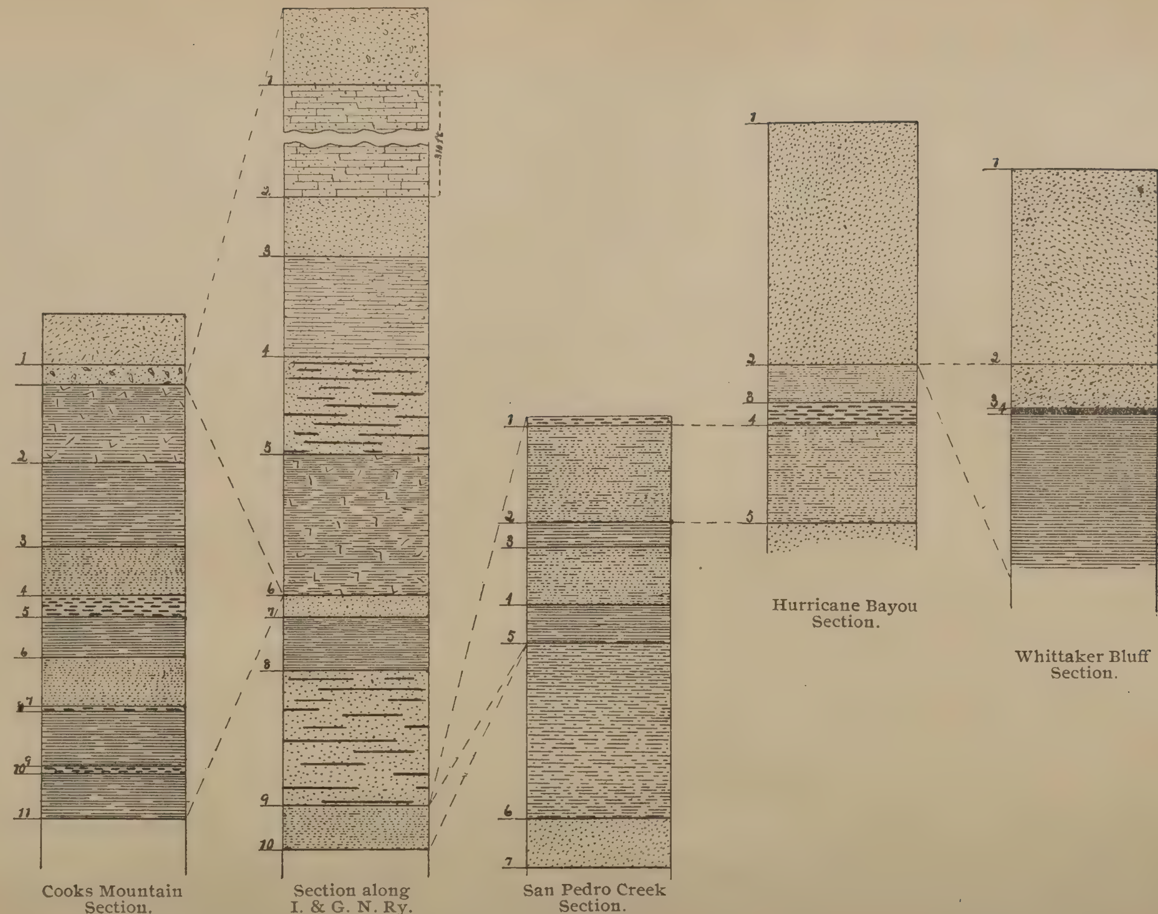

Fig. 1.

Tyler); Tyler prairie, on the southeastern border; Nevill's and Mustang prairies, near the western limit. These prairies have a total area of approximately fifty square miles, and strongly resemble each other in soil and general structure. Other small prairies intervene between these, but are generally of very limited extent.

The chief streams are Cypress creek, San Pedro, Hickory and Camp creeks, and Cochino bayou, flowing eastward into the Neches river. Piney creek flows south through Trinity county, and finally empties into the Neches river. In the southern portion White Rock, with its tributaries, Box creek and Tantabogue creek, form the outlet for the drainage of an extensive area. Negro, Lost and Caney creeks, and Hurricane bayou, and the two Elkhart creeks, flow west into the Trinity river.

Throughout the central hilly region several of the higher points are locally known as mountains, the most pronounced of these being Cook's mountain and West mountain. Cook's mountain is a prominent feature of the landscape, rising about one hundred feet above Crockett, and having an elevation of about four hundred and sixty feet above sea level. This mountain rises with a gentle slope from the east and ends abruptly on the west and northwest. Its top is perfectly flat and covered with fragments of ferruginous material and fossiliferous altered greensand. The northwestern corner ends in a narrow peak about thirty feet wide, rising over one hundred and eighty feet above the level of the Hurricane bayou bottoms. From this point an extended view of several miles can be had of the lower level lands lying to the east, north and west. West mountain is the higher portion of the ridge separating the Hurricane bayou drainage from the Little Elkhart, and rises to an elevation of about four hundred feet. It is a sandy belt, covered with a conglomerate iron ore and ferruginous sandstone.

In the northeastern portion some of the high sandy hills have elevations of from five hundred and thirty to five hundred and fifty feet above sea level, Houston mound, the most prominent of them, having a still higher elevation.

GENERAL GEOLOGY.

The geological section of the county shows the Quaternary deposits to be spread over a greater part of the northern division to a greater or less depth, with a few isolated patches scattered throughout the southern portion. The general dip of the beds is in accordance with the Tertiary and later deposits of Eastern Texas—that is, from northwest to southeast approximately. Some local variations occur, but these are not generally to any great degree, and where such changes appear they are altogether due to some local cause—most of them to the erosion of underlying deposits or beds of sand. These sands are acted upon by the underground flow of water, which, finding its outlet in the numer-

ous flowing springs found everywhere, carry off enough of the sand to allow the upper and more compact beds to assume positions at various angles from the general uniform dip. The great divisions, therefore, lie from northwest to southeast, beginning with the oldest. The general dip of the lower or Eocene beds may be placed at about sixteen feet per mile, and that of the upper, or Miocene (Fayette) beds, at from ten to twelve feet. These dips are as approximately correct as the time and means of measurement at the command of the Survey can make them. The Basal beds of the section are altogether of the upper division of the Eocene deposits,, and occupy the county from the Anderson county line southerly to near Crockett. The southern division belongs to the Miocene.

The general section shows the following approximate thickness of the several deposits:

Recent.—River alluvium, found in the flood plains of the rivers and creeks and some of the second bottom lands	14 to 20 feet.
Quaternary.—Yellow, brown and gray sands, red sandstones, gravels and conglomerate iron ores, in the northern portion; siliceous pebbles, fossil woods, and prairie lands, in the southern districts . .	50 to 60 feet.
Miocene.—Gray sands and sandy clays, gray sandstones and thinly laminated blue and brown shaly clays, containing crystals of selenite and gypsum, and the blue sandy clays of the pine prairie region of the southeast, and lignite	250 feet.
Eocene.—Altered glauconitic sandstones, laminated iron ore, brown fossiliferous and indurated yellow fossiliferous sands, green marly clay and greensands, black or dark clay with limy concretions, with gray plastic clays and fossiliferous greensand marls	400 feet.

RECENT.

A considerable extent of Recent deposits occurs along the borders of the Neches and Trinity rivers, and also throughout the wide bottom lands forming the flood plains of the different creeks flowing through the southern portion of the county. The structure of these deposits are to a great extent laminated. Deposits of clays and sands in laminæ, having an irregular thickness varying from one-eighth to one-half inch, and dipping at various angles and in several directions, form the bulk of these beds. The dip and course of these deposits vary with the structure or outline of the area covered. Those along the various creeks and bayous are usually very much undermined, but where the structure can be made out the angles of the dip are generally very small and toward the stream channel. On the rivers, and particularly along the Trinity, where high bluffs approach the river at many places, the Recent deposits lie in great bay-like indentations. The structure of these deposits show a basin-like formation, dipping from the high outward rim or boundary toward the center, and frequently dipping down stream at an ever decreasing angle. The mate-

rials forming these deposits are similar to those of the deposits forming along the creek flood plains. A section of a bluff of Recent material shown on the Trinity river, about a mile south of Hall's Bluff, shows:

1. Thinly laminated black or dark blue sands and clays, dipping at angles varying from less than one to eighteen degrees, the higher angles being towards the base . . . . 14 feet.
2. Bed of iron ore visible in river bottom . . . . 1 foot.

The thickness of these deposits will not probably exceed twenty feet at their greatest extension, and the greater portion of them will not exceed fourteen feet. As is usual in the structure of such flood plains, the highest portions are close to and along the bank of the stream. In places this is so strongly marked that, while the bank is perfectly dry, shallow sheets of water or marshy land is found at some distance away from the stream. The remains found in these beds are usually stumps, branches and leaves of the vegetation now growing along the banks of the streams. Shells of the fauna living in the neighborhood are occasionally found imbedded in the sands.

QUATERNARY.

The Quatenary deposits occupy a considerable area. They form an almost continuous covering overlying nearly the whole of the northern or more elevated portion. In the southern region they do not appear to be so widely distributed, although found capping most of the higher points, as well as filling with a thin deposit of gravel and silt, some of the valleys lying among the Miocene beds, and forming many, if not the whole, of the prairies so extensively distributed throughout the lower region. These deposits have been estimated to have a thickness of between fifty and sixty feet, and naturally fall into two divisions:

1. Prairie soils, gravels and river alluvium, corresponding to the Bluff Formation of Hilgard . . . . 4 to 10 feet.
2. Conglomerate iron ore, ferruginous sandstones, gray, yellow and brown sands, siliceous and crystalline pebbles and gravel, and occassional lenticular deposits of clay . . . . 50 feet

PRAIRIES.

Scattered over the county there are numerous small prairies, some of which do not exceed a limit of one square mile; others—such as East prairie, on the southern boundary; Tyler prairie, adjoining East prairie; Nevill's prairie, near the centre of the southern portion—occupy areas covering from seven to thirty square miles. Mustang prairie and Towsend prairie have each an erea of about two square miles, and Murchison's prairie, on the nothern border, covers an area nearly two miles square.*

*Murchison's prairie belongs to the Eocene period, and is probably of Jackson age.

East and Tyler Prairies.—For all practical purposes these two prairies may be considered as being one. In their general elevation and chief characteristics they closely resemble each other, and a narrow belt of timber of recent growth forms the only line of division between them. They lie along the southern boundary, Tyler prairie extending for some miles into Trinity, the adjoining county. The portion north of the county line covers an area of nearly seven square miles. Their surface presents a level stretch of country, devoid of trees and covered with a dark gray sandy or silty soil. Sections obtained along a creek flowing through the main portion of Tyler Prairie show this surface soil to be underlaid by a thin stratum of siliceous gravel.

The action of the streams along the northern boundary of these prairies gives them the appearance of being slightly elevated above the neighboring country. This, however, is not the case, as at a short distance north a range of high gray sandy hills, capped with gravel, rise to an elevation of from thirty to fifty feet above the level of the prairie. The surrounding country is covered with a scattering growth of oaks and other timber, which appears to be gradually encroaching upon the prairie.

Nevill's Prairie.—This prairie lies near the center of the extreme southern portion of the county, and occupies an area of nearly thirty square miles. It has a general elevation of about three hundred feet, and slopes slightly to the westward.*

In general appearance it greatly resembles Tyler prairie. The surface soil is a dark gray silty sand, from two to four feet deep, overlying a thin stratum of siliceous pebbles and fossil wood. A characteristic feature, not noticed in Tyler, is the presence of extensive areas of light gray, almost white, unproductive crawfishy lands, which are particularly marked in the western portion.

To the north, this prairie is skirted by a range of high ground, made up of gray sands and siliceous gravel with small fragments of fossil wood, and covered with timber. This is a continuation of the high gravel and sandy ridge extending along the north side of Tyler prairie. Some of the higher grounds on the southeastern edge, on the south corner of the John Welch headright, are capped by the light gray sandstones of Miocene age.

The timber areas are gradually encroaching upon the level lands, and already clumps or groves of young pines dot the western half. Between the western edge and the Trinity river there is an extensive tract of flat gray sandy land, which probably at one time belonged to the treeless prairie, but which is now covered with a heavy growth of pine and oak with some walnut and other trees.

*The levels of the Trinity, Cameron and Western Railway give Weldon an elevation of two hundred and ninety-four feet, and Hydes' bluff two hundred and twenty-one feet.

In structure these two southern prairies show practically the same section. Both are covered with a dark gray soil from two to four feet in thickness. In both regions the soils rest upon a thin stratum of siliceous and crystalline pebbles intermixed with great quantities of fossil wood. The following sections show the strata exhibited in both:

SECTION OF TYLER PRAIRIE.

1.	Grayish black sandy soil	2 feet.	
2.	Thin deposit of pebbles and fossil woods		4 to 8 in.
3.	Yellowish gray sand	6 feet.	
4.	Orange yellow clay		2 to 6 in.
5.	Dark gray laminated clay with fragmentary impressions of leaves	40 feet.	
6.	Dark gray clay interstratified with sand		
	Total	49 feet.	

SECTION OF WELL ON NEVILL'S PRAIRIE.

1.	Dark soil	4 feet.	
2.	Thin stratum of pebbles of fossil wood		4 to 6 in.
3.	Gray sandy clay or clayey sand }	30 feet.	
4.	Blue sand }		
5.	Lignite, earthy, mixed with sand	2 feet.	
6.	Blue sandy clay	47 feet.	
	Total	83 feet.	

The physical condition of the soils of these prairies show them to contain over 77 per cent of silt.

The surface of these two prairies (Tyler and Nevill's) lie almost in the same plain, both having an elevation of about three hundred feet, and the high gravel ridge extending across the northern end of Nevill's prairie has its continuation stretching along the northern side of Tyler prairie.

MUSTANG PRAIRIE.—Mustang prairie forms a flat region of about one and one-half square miles in extent, and covering the greater portion of the J. H. Cummin's headright. The surface soil is dark gray, almost black, and about two feet thick. The pebbles, so marked as forming a continuous stratum in the other prairies, are not so decided in Mustang, but appear to be intimately mixed with the lower half of the soil deposit. The underlying bed is a dark yellowish gray clay, containing great quantities of gypsum in a crystalline form. This prairie lies at a higher elevation than any of the other prairies to the south, and is surrounded by hills of siliceous gravel and gray sand.

Mustang prairie shows a somewhat similar structure as Tyler and Nevill's prairies. The soil is of the same silty character and rests upon a substratum of gravel. It differs somewhat from the other two in that

its underlying beds, where exposed, appear to be a dark yellowish gray clay containing numerous crystals of gypsum. A section of this prairie gives:

1.	Black soils, containing numerous siliceous pebbles and fossil wood near the base	1 to 2 feet.
2.	Dark yellowish gray clay containing crystals of gypsum	4 to 8 feet.

This prairie is surrounded by high gray sand hills.

Townsend Prairie.—Townsend prairie is a small area lying on the east side of the T. R. Townsend headright. In extent it does not exceed a square mile, and lies in a basin-like form in the midst of brown sandy and gravelly hills. The surface soil of this prairie is a brown and red colored silty sand, similar to that forming the surrounding higher grounds, lying upon an under stratum of dark gray sand with laminæ or small masses of dark blue clay containing gypsum crystals.

All the prairies are, for the most part, devoid of timber. A scattering growth of oaks, with a few scattered pines, surround them and crown the higher lands on all sides. Within recent years, however, the timber has shot out long, narrow, tongue-like strips of woodland, which now reach to near the center of some portions of them. East prairie and Tyler prairie, originally one unbroken stretch of treeless sandy plain, are now separated by a narrow belt of trees. Mustang prairie has also been nearly cut in two by a similar strip of woodland, and Nevill's prairie in many places, particularly towards the west, presents a dense foliage of young pines. On all sides the timber is encroaching upon the prairies, and year after year narrowing the area, and in a few years, except where under cultivation, the treeless prairies will be but a memory of the past.

The timber is also encroaching on Murchison prairie, in the northern portion of the county, and long belts of oaks and other trees are now interspersed with open spots of what, not many years ago, was a treeless country.

The origin and absolute original extent of these prairies have not yet been completely worked out. They lie around the heads of their respective drainage systems. No streams flow completely through them, although several small ones rise from springs and other sources within their areas. It is not improbable that their origin is due primarily to their having been lakes, or marshes subject to deep and long continued inundations, within a comparatively recent period; and that, owing to a change in the level of the Trinity river, and consequent silting up of the connection between them and the waters of the river, they were gradually filled up by the washings from the surrounding higher grounds. In this stage the prairies would remain treeless. It is also probable, from their structure and the condition of their mate-

rials, that the most southerly—Nevill's and Tyler prairies, with their connecting flat wooded areas—may have formed, within comparatively recent times, a continuous lake, or the channel of some wide stream, probably a section of the present Trinity river, since a depression of only about forty feet would again place both among the overflow or marshy lands connected with the Trinity. With the advance of the streams from the outside towards the center of the prairies, and the cutting out of their channels, the resultant drainage of the area would ultimately render the soils suitable for the growth of arborescent foliage; and now, at the present time, as before noted, the trees of the surrounding neighborhood are beginning to encroach upon the plains.*

The southern prairies have, for the present, been placed among the Quaternary deposits. If they belong to this period, they must be placed among the youngest members, and it is very probable that they ought to be classed with the older division of the Recent.

DRIFT.

With the exception of a few miles included in the area embraced by Murchison's prairie, and the small area further east occupied by the laminated iron ore, the drift deposits of the Quaternary cover the whole of the northern division of the county, and extend as far south as Crockett, and towards the western portion a few miles further south, attaining their maximum thickness of sixty feet in the neighborhood of Grapeland. Wells bored in that vicinity show a section of yellow sand over fifty feet in thickness.

Two series occur in this region — a modified or partially stratified series of deposits, and a totally unstratified heterogeneous mass of sands, gravels and pebbles. These have not as yet been differentiated, and although there can be no doubt as to there being a wide difference between the times of their deposition, no distinction has been made in this report between the two. Further observations are needed to satisfactorily separate the modified from the unstratified materials.

The general facies are gray, yellow and brown sands, gravels, siliceous and ferruginous pebbles, conglomerate iron ore and ferruginous sandstones, with occasional deposits of clay.

North of the Big Elkhart, on the old Murchison place, several stream cuttings show the sands and clays to have a stratified structure. Near Hancock's gin, and on the Hall's bluff road a few miles east of Udston postoffice, lines of stratification are also visible in many of the cuttings. In the eastern portion of the county numerous cuttings show stratified deposits of brown and yellow sand. In many places the gravel and sand are intimately mixed, and at others the sands show signs of erosion

* Winchell, A. J. S., Second series, Vol. XXXVIII., p. 332 (1864).
Lesquereux, Second Report of Arkansas, 1860, p. 323.
Lesquereux, A. J. S., Second series, Vol. XXXIX., May, 1865, p. 317.

in the form of pot holes which are filled with gravel. In many localities the deposits of yellow sand end abruptly, and the overlying gravel bends down over the break, and by thickening assumes the place of the sand for long distances.

In the region between the two Elkharts, on the western side of the county, the drift deposits consist for the greater part of ferruginous sandstones broken in small pieces and intermixed with a brown sand. South of the Little Elkhart the broken sandstones give place to sand and gravel and conglomerate iron ore with great quantities of siliceous pebbles. At Hancock's mill, on Yellow creek, the conglomerate iron ore is intimately associated with blocks of ferruginous sandstone, sometimes measuring 12x10x4 or even 6 feet.

Along the north side of Hurricane bayou from Udston postoffice, on the south side of the Ramon de la Garza tract, eastward as far as Hickory creek and north to the south side of San Pedro on the Stow headright, the deposits are represented by conglomerate iron ores, gray and brown sand and siliceous pebbles, in some places exceeding twenty feet in thickness. A well dug on the J. Malon headright shows a gray sand and deposit of siliceous gravel to a depth of over twenty-two feet, and on the J. M. Manes headright, about a mile north of Hurricane bayou, a well thirty feet deep passed through pebbles and gravel and ended in a yellowish colored sand. Near the town of Augusta siliceous gravel and sand covers a small area south of the school house. Gravel and sand also occur on the north side of the Daniel McLean league and northward to near the Neches. South of the same bayou deposits of the brown, gray and yellow sand, with siliceous pebbles, occur as far south as the Alabama and Crockett road.

Beginning near Brookfield bluff, on the Trinity river, and extending eastward as far as the Trinity county line, in a nearly southeast direction, there lies a broad gravel covered ridge which rises to a considerable elevation above the surrounding gray sandy country. It is very irregular in width and at one place spreads wide enough to enclose Mustang prairie in its course.

Isolated patches of gravelly material are found at various other places. These localities all have approximately the same altitude with reference to the underlying beds, and would appear to indicate that the Quaternary drift deposits at one time covered the whole country, but have been removed by subsequent denudation.

MIOCENE.

The deposits classed by Dr. Penrose (First Annual Report, p. 47) as Fayette beds, are here assigned to the Miocene. They comprise a series of gray sands and sandstones and grey laminated clays. Toward the base there is a series of blue and brown laminated gypsum-bearing beds, the gypsum usually occurring as selenite, or in crystalline form.

BLUFFS ON TRINITY RIVER, HOUSTON COUNTY.

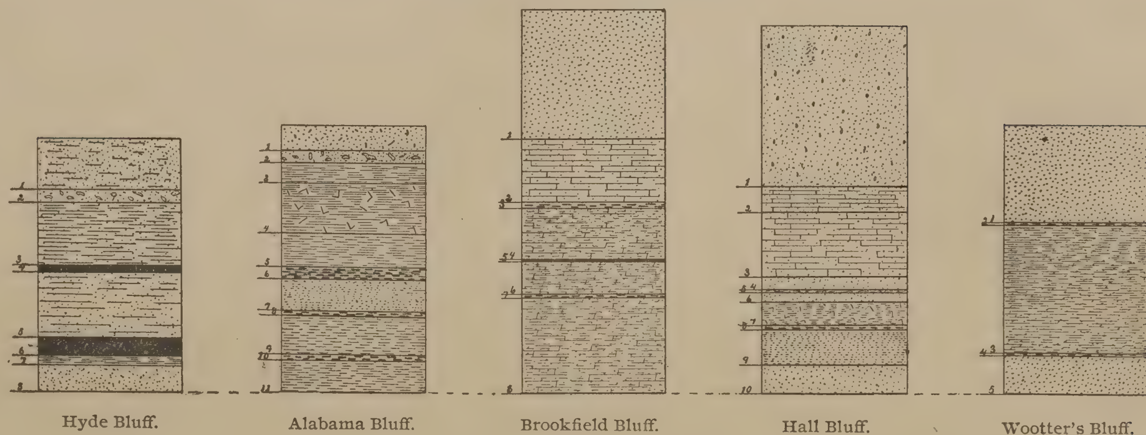

Fig. 2.

In the western portion of the county these clays give place to massive dark brown sands and clays, containing quantities of broken plant remains. Both these brown sands and clays contain sheet-like formations of crystalline gypsum, usually filling the joints or fractures of the beds. In the southeastern regions the deposits are made up of dark blue and chocolate colored clays and lignitic deposits. The total thickness of the beds included as Miocene is placed at two hundred and fifty feet. The available lignite beds are all confined to this age.

The northern boundary of these beds begins in the northeastern portion of the county, near the north side of the Antonio Borrazo league, and passes westerly as far as the J. Pruit headright, about two miles southwest of Augusta postoffice. From that place it turns and extends south nearly eight miles, to the J. D. English headright, where the line again turns west. Passing along the south side of Hurricane bayou, it bends southward around the town of Crockett, and thence westward to within a short distance of the Trinity river, near Brookfield's bluff. From this point the line turns south, and crosses the Trinity near Alabama postoffice.

The outline of this border is exceedingly irregular. It is broken up into small narrow inlets, or stream channels, and although there appears in most places to be an almost uniform continuity between the beds of the two periods, there are in others strong evidence of a long continued erosion of the older beds before the deposition of the newer. This is visible in the neighborhood of Crockett, near Cook's mountain, and several other localities. Contacts between these overlying Miocene deposits and the underlying Eocene beds have been observed in various places along this line of demarcation, but such exposures are very few. The greater portion of the region is covered with drift materials to such an extent that the underlying beds are nearly everywhere covered to a considerable depth.

The following sections obtained at different localities occupied by these deposits show the structure of the beds classed as Miocene:

First. Section at Alabama bluff on the Trinity river.

1.	Black sandy loam	5 feet.
2.	Laminated clay with gypsum	5 feet.
3.	Fossiliferous greensand, visible	5 feet.

The dip of the beds in this section is south twenty degrees east, three degrees.

Near the north end of the same bluff, and about a quarter of a mile north of this same section, the bluff shows a section of:

1.	Dark silty and loamy soil	4 feet.
2.	Conglomerate of stained siliceous pebbles and iron ore and silicified wood stained brown	2 feet.
3.	Fossiliferous greenish blue clay	4 feet.
4.	Greensand	5 feet.
5.	Clay ironstone	10 inches.
6.	Fossiliferous clay, visible	5 feet.

The dip of these beds is in the same direction as those in the section at the south end of the bluff, but the angle is slightly steeper. These two sections show the contact of the Miocene and Eocene deposits at this place to be but slightly unconformable. This unconformability is represented by the slight variation in the dip of the beds and the introduction of a deposit of dark laminated gypsum-bearing clay.

Going south, along the same river, to Hyde's bluff, a distance of a little over fifteen miles; the section shown in the bluff is as follows:

1.	Dark yellowish brown clayey loam and sand	8 feet.
2.	Conglomerate of broken fragments of nodular iron ore, stained siliceous pebbles, iron stained fossil wood, and coarse brown sand and fine gravel	2 feet.
3.	Dark blue sandy clay, with the upper surface stained to a depth of one foot by the brown ferruginous matter of the conglomerate, containing decomposed iron pyrites . . .	10 feet.
4.	Lignite	2 inches to 2 feet.
5.	Light grayish blue sand and gray clay interlaminated . . .	10 feet.
6.	Lignite	2 to 4 feet.
7.	Dark purple colored clay	$1\frac{1}{2}$ feet.
8.	Gray sand containing rounded and flat oval shaped concretions, or bowlders, of a gray indurated sand, to water . .	4 feet.

Dip south sixty-eight degrees east, three degrees.

Five miles east of Hyde's bluff, a well, bored eighty-three feet, shows a section of:

1.	Dark soil (paririe)	4 feet.
2.	Thin stratum of pebbles	4 to 6 inches.
3.	Gray sandy clay, or clayey sand and blue sand	70 feet.
4.	Lignite similar to that at Hyde's bluff, in No. 4 of section . . .	2 feet.
5.	Grayish blue sand	

Near Lovelady the section of a well shows:

1.	Gray sand	1 foot.
2.	Stiff laminated gray clay with interlaminæ of gray sand and containing fragments of leaves	10 feet.
3.	Yellow sand and clay	27 feet.
4.	Blue sand with lignitic streaks	30 feet.

No. 4 of this section is reported as being found in all the wells of this neighborhood at a depth of between thirty and forty feet.

On the E. Clapp headright, near Porters' springs, a stream cutting shows a section of:

1.	Gray sand and small blocks of conglomerate ore	20 feet.
2.	Red sand	2 feet.
3.	Stratified greensands	4 feet.
4.	Dark pink interstratified sand and clay	4 feet.

A mile and a half northwest, on the same creek, near Mr. W. G. Brazeal's house, a section of the bank shows:

1. Sand and gravel, Quaternary drift . . . . 2 feet.
2. Brownish gray, partially stratified sand . . . . 5 feet.
3. Heavy deposit of gray sand containing broken leaves and sheets of gypsum . . . . 6 feet.
4. Dark colored lignitic sand, containing numerous fragments of plants and gypsum . . . . 8 feet.

Near Crockett, along the south side of Cook's mountain, a creek shows a section exhibiting the contact between the underlying fossiliferous deposits of the Eocene and the overlying gypsum-bearing clays. The following is a section from this place:

1. Ferruginous gravel, talus from mountain . . . . 4 feet.
2. Thinly laminated brown clays . . . . 4 feet.
3. Thinly laminated dark blue clay with interlaminæ of brown sand and crystals of selenite . . . . 6 feet.
4. Fossiliferous brown sand . . . . 10 to 15 feet.
5. Laminated blue plastic clay, stained brown in places . . . . . . 4 feet.

A short distance up the creek, near the Alabama road crossing, the banks show a section of:

1. Broken sand beds . . . . 5 feet.
2. Stratified clays and sands, the clays varying from dark brown to black, and thinly laminated, the sand from a gray to a yellow color, and in strata of two to six inches . . . . 4 feet.
3. Thin stratum of gray and brown laminated clay and sand . . . . . 8 inches.
4. Thin stratum of soft brown sandstone . . . . 2 inches.
5. Same as No. 3 . . . . 4 feet.
6. Black sandy clay, containing visible plant impressions . . . . . . 1 foot.

On the road, the beds underlying this section, comprise:

1. Gray sandy soil . . . . 2 feet.
2. Yellow sand with ferruginous and siliceous pebbles . . . . . 1 foot 6 inches.
3. Brown sand . . . . 2 feet.
4. Gray sand, in places indurated to a soft sandstone . . . . . . 6 feet.

All these beds dip south sixty degrees east, three degrees.

Passing toward the east, the same gypsum-bearing clays occur near Calthorp postoffice, on the John Box headright. A section of the hill near the old Hudson postoffice site, gives:

1. Gray sandy surface soil . . . . 1 to 6 feet.
2. Brown sand with siliceous pebbles . . . . 4 feet.
3. Thinly laminated sandy clay and clay . . . . 10 feet.
4. Yellow gypseous clay . . . . 3 feet.
5. Thinly laminated sand and clay . . . . 15 feet.

About two miles south of this section, a cutting of Flat creek shows a section of:

1. Surface soil . . . . 1 foot.
2. Gray sand, with occasional pockets of siliceous pebbles . . . . . . 14 feet.
3. Thinly laminated blue sandy clay . . . . $4\frac{1}{2}$ feet.
4. Lignite, visible . . . . 4 feet.

Going down the creek, the lignite thins out and shows the underlying material to be a purple colored clay.

On the J. Bethed headright, about three miles southeast of the last section, the same lignite appears in a cutting, showing a section of:

1.	Surface soil of gray sand	1 foot.
2.	Thinly laminated clay and sand	4 feet.
3.	Laminated brown colored clay	1 foot.
4.	Lignite, visible	4 feet.

EOCENE.

These deposits are covered, throughout their greater extent, by deposits of the Quaternary sands and gravels, and in some places by heavy deposits of conglomerate iron ore.

In areal extent the Eocene deposits occupy the whole of the northern portion of the county, extending from near Crockett northward to the Anderson county line, and from the Neches river on the east to the Trinity on the west. Their southern limits conform to the northern boundary of the Miocene deposits already described.

The Eocene deposits of this region may be placed as the equivalent of the Claiborne deposits of Alabama and Mississippi, although the evidence, so far as the details have at present been worked out, seem to place the upper division in a position corresponding to the Jackson of Louisiana and Mississippi,* and the Smithville beds of Dr. Penrose's Colorado river section.

The following sections show the general relations of the deposits belonging to the Eocene in this part of the State. As the deposits dip in a generally southeast direction, and the beds lie apparently conformably to each other, in the northwest corner of the county the sections will show the older deposits.

Section at Wootter's bluff, Trinity river:

1.	Brown and yellowish brown sand	10 to 15 feet.
2.	Thin stratum of clay ironstone	1 to 3 inches.
3.	Dark gray micaceous clay, weathering brown on the outside	20 feet.
4.	Clay ironstone	1 to 2 inches.
5.	Dark blue or bluish black micaceous clayey sand	2 to 6 feet.

Small rounded lumps of lignite occur in association with the dark blue sands No. 5.

South of this about six miles, at Hall's bluff, on the same river, a section of the bluff shows:

1.	Quaternary gravel	25 to 20 feet.
2.	Fossilferous sandstone containing casts of shells	4 feet.
3.	Red sandstones—no fossils observed	10 feet.
4.	Yellowish white sand	2 feet.
5.	Brown clay with gypsum crystals	6 inches.
6.	Yellowish white sand	1½ feet.

*Geological Survey of Louisiana, First Report, p. 90; Second, p. 7.
Hilgard Report of Mississippi, 1860, p. 128.

7.	Sand same as No. 5	$3\frac{1}{2}$ feet.
8.	Irregular stratum of clay ironstone bowlders	8 inches.
9.	Dark greensand, weathering brown on outside, containing fish teeth	6 feet.
10.	Brown sand	4 feet.

Dip south twenty degrees east, three degrees.

Still further down the river, at Brookfield's bluff, five miles below Hall's bluff, the section shown is:

1.	Quaternary sand and gravel in ridge about one hundred yards east of the river	20 feet.
2.	Brown sandstone	10 feet.
3.	Clay ironstone	1 foot.
4.	Laminated dark blue sand and light gray clays containing decomposed iron pyrites	8 feet.
5.	Lignite	2 inches.
6.	Same as No 4	5 feet.
7.	Thin seam of ironstone	6 inches.
8.	Same as No. 4, getting darker in lower portion of bed, and covered in places with a yellow efflorescence of sulphur	15 feet.

No. 8 of the section extends below the line of low water level. This bed is also broken by numerous small springs issuing from it. These springs give off sulphuretted hydrogen gas in considerable quantities, and bubbles of the same gas are seen to rise in great quantities from the bed of the river.

The next section on the river occurs at Alabama bluff, about six miles in a straight line further south (nine miles by river). This section shows the last deposits of the Eocene materials.

Passing again to the northern portion of the county, near Harmon's mill on the Stephen Rodgers headright, the section there shown gives:

1.	Gray sand	60 feet.
2.	Indurated yellow fossilferous sands containing shells	10 feet.
3.	Bluish green marly sand in well	7 feet.

Four miles eastward from this section on the southeastern corner of the Jose Maria Procella headright a section gives:

1.	Gray sand, broken sandstones and gravel	26 feet.
2.	Brown, marly sand, containing ostrea shell chiefly	2 feet.
3.	Greenish blue marly sand, containing numerous shells, chiefly of the *Cardita planicosta* and *Cerithium whitfieldi*, both of large size	10 feet.

South of this place, where the Rusk and Crockett public road crosses the San Pedro creek, the south bank of the creek shows a section of:

1.	Gray sand, near San Pedro church	25 feet.
2.	Brown sand and altered greensands	4 feet.
3.	Brown stratified ferruginous material, with thin laminæ of iron ore.	2 feet.
4.	Yellow indurated fossiliferous greensand marls, packed with shells visible	20 feet.

No. 4 is the same or the equivalent of the bed found at Harmon's mill, and underlying the iron ore near Robbin's ferry, shown in the next section.

Near the Robbin's ferry across the Neches, on the Leonard Williams headright, a section gives:

1.	Gray sand	6 in. to 1 foot.
2.	Laminated iron ore	4 to 10 in.
3.	Indurated yellow fossiliferous marl same as on San Pedro creek	2 feet.
4.	Yellow sand	10 feet.
5.	Pipe clay	2½ feet.
6.	Fossiliferous green clay	5 to 6 feet.
7.	Red clay	3 to 4 feet.
8.	Blue marls containing fossils	18 feet.
9.	Brown laminated sand, visible	5 feet.

A section on Silver creek, and apparently lying below the last section, gives:

1.	Red sands with siliceous pebbles and gravels	1 to 2 feet.
2.	Rounded concretions of iron ore, with yellow ochre	6 inches to 1 foot.
3.	Ferruginous sandstones	
4.	Laminated blue and brown sandy clay and sand	40 feet.

Toward the southern edge of the area underlaid by the Eocene deposits, sections show the general distribution to be as follows:

Section at K. Jones' well, Nevel C. Hodges' headright:

1.	Yellowish brown sandy clay	6 feet.
2.	Joint clay	6 feet.
3.	Thinly laminated black fossiliferous sand	4 feet.
4.	Bluish green fossiliferous marls	14 feet.

The hill at Hagues' gin, northeast of the last section, shows a section of:

1.	Brown sand and ferruginous gravel	10 feet.
2.	Yellow and brown sand with clay and fine gravel	5 feet.
3.	Blue and yellow mottled clay, with thin stratum of white calcareous nodules	5 feet.
4.	Brown sand	5 feet.
5.	Gray sand overlying in Jones' well	

The Cook's mountain shows section:

1.	Brown ferruginous sandstones with occasional casts of fossils	10 feet.
2.	Altered glauconitic sand, yellow colored and crossbedded	40 feet.
3.	Covered up with debris from top of hill	55 feet.
4.	Stratum of brown ferruginous sandstone containing *ostrea sellæformis*	10 feet.
5.	Iron ore	1 foot.
6.	Brown sand with fossils	15 feet.
7.	Blue laminated clay	4 feet.

On the north side of the bayou this fifty-five feet of covered material is represented by brown sand and sandstones, underlaid by brown and black sandy clay, with occasional seams of ferruginous matter.

MURCHISON'S PRAIRIE.—The only prairie region in the northern portion of the county is that known as Murchison's prairie. This comprises an area of about two miles square, extending over a greater portion of the Jose Maria Procella league, and a portion of the northeastern corner of the Stephen Rodgers headright. Unlike the prairie regions of the southern portion of the county, Murchison's prairie does not owe its existence to lacustrine formation. This prairie, which lies somewhat lower than the surrounding country, appears to owe its prairie origin and general absence of trees to the impervious nature of the subsoils. Wherever drainage has taken place, owing to the cutting of the stream channels and the consequent carrying away of the water, trees are springing up and encroaching upon the treeless area. Like the prairies in the southern portion of the county, Murchison's prairie will, in a few years, be as well wooded as the surrounding country.

ECONOMIC GEOLOGY.

SOILS.

The soils of the county are all fit for cultivation. The virgin soil is in most places of a fairly good grade, but those under cultivation are rapidly deteriorating, and some of them have already reached a stage which renders them unprofitable for the cultivation of cotton, the staple product of the county, and are nearly in the same condition for corn production, especially the upland gray sandy and light prairie soils.

This deterioration can readily be noticed. At first small spots appear in various portions of the field, upon which the cotton plant, never very vigorous, begins to get brown and shriveled, and finally dies. These spots may not at first include more space than is covered by two or three plants, but as the season passes they grow larger, until the area included by them forms a considerable portion of the ground under cultivation. With each succeeding cotton crop this area increases. While as yet in no place observed has corn failed to grow on these spots, this crop also shows a falling off from preceding years.

Physically there appears to be no difference between these unproductive areas and the surrounding portions of the land, but chemically the constitution of the two differ in many respects. The following analyses show the chemical as well as the physical conditions of the two. Both are taken from the same field and not very far apart. Nos. 1329 and 1330 show the cotton producing soil, and Nos. 1327 and 1328 the character of one of the areas in which the cotton dies:

	No. 1329.	No. 1330.	No. 1327.	No. 1328.
Insoluble in hydrochloric acid	96.10	96.92	96.00	97.00
Soluble silica	0.22	00.08	0.20	0.12
Iron	0.95	1.70	1.23	0.90
Alumina	0.35	Trace	0.00	Trace
Lime	0.62	0.41	0.29	0.30
Magnesia	Trace	Trace	Trace	Trace
Soda	0.32	0.20	0.81	0.90
Potash	0.10	0.09	0 14	0 06
Sulphuric acid	0.03	0.06	0.06	0.05
Phosphoric acid	0.03	0.07	0.026	0.02
Water	0.14	0 08	0 08	0 04
Organic matter	1.26	0.78	1.58	0.66

The physical condition of these soils is shown by mechanical analyses to be:

	No. 1329.		No. 1330.		No. 1327.		No. 1328.	
	Fixed.	Volatile.	Fixed.	Volatile.	Fixed.	Volatile.	Fixed.	Volatile.
Silt	55.15	0.87	47.50	0.44	71.84	0.16	36.20	0.33
Fine sand	26.73	0.19	21.50	0.11	15.00	0.10	38.98	0.36
Coarse sand	9.82	0.08	17.30	0.10	6.69	0.18	17.53	0.07
Gravel	4.15	0.09	4.76	0.04	2.23	0.10	4.62	0.04
Coarse gravel	1.21	0.09	3.12	0.05	0.75	0.09	0.72	0.02
Stones	1.62	0.00	5.08	0.00	2.86	0.00	1.13	0.00

These soils are practically in the same physical condition. Their differences of production and non-production appear to be solely due to the variations in their chemical composition, and both are on the verge of utter exhaustion, while No. 1327 has already reached that stage as far as cotton is concerned.

The same condition exists in many of the prairie soils. A specimen obtained from Tyler prairie gives, on analysis, a result equally positive.

Analysis of soil and subsoil from Tyler prairie producing six hundred pounds of seed cotton and twenty bushels of corn per acre:

	No. 1341.	No. 1342.
	Soil.	Subsoil.
Insoluble in hydrochloric acid	96.50	96.75
Soluble silica	0.12	0.18
Iron	1.07	0.75
Alumina	1 13	Trace.
Lime	0.23	0.33
Magnesia	Trace.	Trace.
Soda	0.41	0.33
Potash	0.06	0.11
Sulphuric acid	0.08	0.14
Phosphoric acid	0.03	Trace.
Water	0 20	0.36
Organic matter	1.44	1.34
Total	101.27	100.29

	Physical Condition.			
	Soil.		Subsoil.	
	Fixed.	Volatile.	Fixed.	Volatile.
Silt	86.68	1.32	77.82	1.18
Fine sand	7.88	0.08	5.43	0.07
Coarse sand	1.61	0.03	4.16	0.09
Gravel	1.68	0.05	3.15	0.09
Coarse gravel	1.98	0.07	5.81	0.21
Stones	3.62	0.00	1.99	0 00
Total	100		100	

None of the other prairie soils have as yet been analyzed, but will, without doubt, disclose a similar condition of affairs in all of them except Murchison's prairie, lying in the northeastern portion of the county. This exception is altogether due to a difference in the origin and structure of the prairie.

An analysis of the black soils of the county show them to have chemical and physical conditions greatly superior to those of either the gray upland or prairie soil.

Analyses of black soils from near Brookfield's bluff:

	No. 1331. Soil.	No. 1332. Subsoil.
Insoluble in hydrochloric acid	89.58	88.00
Soluble silica	0.12	0.12
Iron	3.68	4.30
Alumina	Trace.	2.60
Lime	0.48	0.47
Magnesia	Trace.	Trace.
Soda	0.60	0.45
Potash	0.16	0.09
Sulphuric Acid	0 06	0.07
Phosphoric Acid	0.09	0.06
Water	0.68	0.84
Organic Matter	4.44	3.38
Total	99.89	100.48

	Physical Conditions.			
	Soil.		Subsoils.	
	Fixed.	Volatile.	Fixed.	Volatile.
Silt	26.53	7.49	31.82	2.06
Fine sand	12.21	0.27	8.05	0.20
Coarse sand	34.18	0.70	33.72	0.80
Gravel	15.10	0.38	19.24	0.51
Coarse gravel	0.86	0.10	1.67	0.09
Stones	2.18	0.00	1.84	0.00
Total	100		100	

These black soils may be classed as medium soils, although the analyses given above show this particular soil to be somewhat deficient in alumina to enable it to stand any prolonged season of dry weather. This character of soil, however, occurs mostly in the bottom, and second bottom lands, and can scarcely suffer at any time for lack of moisture. Some of the specimens collected will, when analyzed, show much more favorable results.

These soils are all transported material. Very little of any other character exists in Houston county. The small areas of the sedentary soils found in the county, arising from the disintegration of the underlying beds, all occur in the northern division. These soils result from a degradation and weathering of the extensive deposits of greensand marls found in that region, and may fairly be inferred to contain most of the ingredients necessary for vegetable life. No analyses have yet been made of this class, but a very fair idea may be obtained from the analyses of the greensand marls given further on in this report.

In estimating the quality of the soils, the classification made by Mr. P. DeGasparin and quoted by Dr. Peters, of the Geological Survey of Kentucky, based upon the percentage of phosphoric acid and potash they contain, has been used. This classification is:

0.20 per cent of phosphoric acid in the soil makes it	Very rich.
0.10 per cent and upward	Rich.
0.05 per cent makes it	Poor.
Between 0.10 and 0.05 makes it	Medium.

Mr. DeGasparin gives 0.04 per cent for potash as a normal average quantity.*

Adopting this mode of classification, a reference to the analyses already given will show that, with the exception of the black soil of the second bottom lands, they may all be classed as poor. The black soil comes under the class of medium soils, both as regards its contained phosphoric acid and potash.

The terms soil and subsoil are, as usually applied, very indefinite terms, and have different meanings according to locality. The term "soil" is generally applied as meaning that portion of the surface immediately under the influence of cultivation, and consequently varies with the depth to which the land is usually ploughed. All the underlying earth is classed as subsoil. The soil under this nomenclature may be anything from three to eight or nine inches, and in many places we frequently hear of a portion of the country being referred to as having no soil at all.

In collecting these soils and subsoils, a uniform rule was adopted of taking for the soil a mixture of the first foot and for the subsoil the next foot. In few places in which there was no apparent change between the first and second foot, the subsoil specimen includes a mixture of the second and third foot, and occasionally in the sandy region, contains more or less of the fourth foot beneath the surface. In every case the soil specimen is mixed with earth extending a few inches beneath that in actual cultivation. This rule was adopted from the fact that no definite or regular depth of cultivation is applied to any portion of the county, and any other method would, under such terms as soil and subsoil be meaningless.

The classification of soils adopted in this report is:

1. The light gray or yellowish sandy soil, belonging chiefly to the drift formations, found extensively throughout the whole of the upland regions.
2. The dark ashy gray and black sandy lacustrine formations of the prairies.
3. The dark, almost black, and brownish black transported soils of the second bottom lands.
4. The black and brownish black sandy clay detrital soils of the areas subject to overflow.
5. The brown or red sedimentary or residual soils formed in the northeastern portion.
6. The southeastern pine prairies.

*Geological Survey of Kentucky, analyses of soils, etc., 1883, p. 12.

LIGHT GRAY OR YELLOWISH SANDY SOIL.

This class of soils is really the most extensively distributed. It covers the whole of the upland region and the greater portion of the central and southern lower lands, and is usually underlaid by a subsoil of a very similar color, and in places where dug out to a depth of four feet showed no change in the general texture. In the northern division of the county the soils are occasionally underlaid by a red, highly ferruginous, sandy clay or altered greensand, and in a belt across the center of the county the gray sands lie upon the dark blue laminated gypseous clays shown in the general section; but throughout the southern portion of the county, where any clayey material occurs, it is usually of a light gray color, very similar to the soils themselves.

These soils are for the most part poor, and the average production of cotton does not exceed six or seven hundred pounds of seed cotton per acre. They are also rapidly deteriorating under the present system of cultivation.

THE DARK ASHY GRAY AND BLACK SANDY SOIL OF THE PRAIRIES.

The soil and subsoil of the southern prairies are, with the exception of Mustang prairie, dark ashy gray in color, and remarkable for the proportion of silty material shown in their structure. The soil of Tyler prairie contains no less than eighty-eight per cent of this material, and a specimen obtained from Nevill's prairie shows the soil of that region to contain —– per cent of silt. The soil of Mustang prairie is a dark ashy gray, shading into black, containing quantities of pebbles in some portions. The subsoil is mixed with numerous crystals of gypsum.

These prairie soils, particularly those of Tyler and Nevill's prairie, are, like the light gray sands, rapidly reaching the limit of deterioration. At present the average crop of cotton on Tyler prairie does not exceed seven hundred pounds of seed cotton, and the corn crop usually produces from twenty-five to thirty bushels per acre. The crops on Nevill's prairie do not exceed this average, and much of the prairie has deteriorated into crawfishy land, producing only a scanty growth of bitterweed.

The total of these areas is approximately forty square miles.

THE DARK, ALMOST BLACK, AND BROWNISH BLACK SOILS OF THE SECOND BOTTOM LANDS.

These soils are made up chiefly of the detritus from the higher lands, and lie mostly within the areas occupying the region between the light gray sandy soils of the uplands and the dark clayey soils of the bottom lands subject to periodical or annual overflow. They are decidedly the best grade of soils in the county, and contain a much larger percentage of the essential ingredients of plant food and approach more nearly

the character of a loam than any of the others.* There are extensive areas of this class, constituting much of the most valuable and productive farming lands.

BLACK AND BROWNISH BLACK SANDY CLAY DETRITAL SOILS OF THE AREAS SUBJECT TO OVERFLOW.

This class of soils is altogether found in the wide bottom lands along the Trinity river and its tributary creeks, occupying extensive areas in the southwestern and southern portions of the county. They are generally made up of an intimate mixture of sand and clay from the washings of the higher lands, and would, under systematic and thorough drainage, form the most valuable of all soils in Houston county. At present no attempt is made to reclaim any portion of them, and they are subject to periodical overflows of from one foot to thirty-five and forty feet, according to their proximity to the river.

THE BROWN OR RED SOILS.

These are the only sedentary soils found in the county, and are mainly found in the northeastern division. Their origin is due to the weathering and disintegration of the extensive beds of greensand marls which they overlie. In the neighborhood of Murchison's prairie, and westward to near Harmon's mill on the San Pedro, this class of soils is extensively developed, and usually averages from one and one half to two feet in depth, and is underlaid by a brown sand containing numerous fragments of broken and comminuted shells. No apparent distinction lies between the soil and the underlying sand, except that the former is a little darker in color, due to the greater proportion of the contained organic matter, and the shells where found are in a very comminuted condition, but are absent throughout the greater portion of the area. No analyses of these soils have been made, but their general texture and adaptability to successful cultivation can be learned by reference to the analyses of the greensand marls from which they have been derived.

SOUTHEASTERN PINE PRAIRIE SOIL.

The southeastern portion of the county is mainly occupied by pine prairies, low flat areas of sand and sandy clay, readily working into a clayey soil, in some places devoid of timber of any sort, and occasionally of a sufficiently clayey nature to retain the surface water to such an extent as to form small stagnant pools.

These soils are, as indicated by their name, usually covered with a

*A loamy soil deposits from 30 to 60 per cent of sand by mechanical washing. Johnson's Agricultural Chemistry, p. 232.

sparse growth of short leaf pine. A very small proportion is in cultivation, and very few sections showing their structure can be obtained.

CRAWFISHY SOILS.

Throughout the county there are numerous spots of "crawfishy" soils. Large areas exist within the limits of Nevill's prairie. They also occur near the site of Old Randolph, west of Lovelady, and at other places. This is due to the conditions of formation in these places. In all cases these soils are of a very porous nature, light gray or almost white in color, and have a loose pebbly subsoil which rests upon a dense clay foundation. The light sandy soil admits of a process of lixiviation by water, which carries down through the subsoil to the surface of the clay the iron, and very probably the vegetable and other valuable ingredients contained in the soil. Here the iron concentrates and gradually forms bog ore or black gravel, which in undrained lands are deleterious to plant life.* These soils are generally devoid of vegetation. The scattering plants found growing upon them appear dwarfed and to be suffering from a lack of nourishment. At present the only plant growth, where any exists, is the common hog, or bitterweed. A corrective remedy might possibly, and doubtless will be, found in a thorough system of drainage in conjunction with a liberal supply of muck.

GREENSAND MARL.

There are extensive deposits of greensand marls in the central and northern portions of the county. They occur as an indurated shell-bearing sand of a yellow color; or a brown, marly and shelly sand; or a grass-green sandy clay, the clay usually in the form of rounded nodules of a grayish green color, thickly specked with small black grains; or as an indurated bluish greensand, containing great quantities of white shells. In addition to these, large quantities of indurated altered glauconitic sandstones, containing casts of shells, occur at different places.

The area underlaid most extensively with these sands is that north of Hurricane bayou and east of the International and Great Northern Railroad. Throughout this region the greensands are exposed in numerous stream channels and washouts, as well as found at various depths in nearly every well dug.

Exposures, in workable quantities, occur in various places along Hurricane bayou and Flat creek, a few miles east of Crockett. They are also found in Mr. K. Jones' well, in the same region, at a depth of twelve feet, where they appear to have a thickness of sixteen feet or more. At Harmon's mill, five miles northeast of Grapeland, the fossiliferous bluish greensands underlie the indurated yellow fossiliferous

* Hilgard's Agricultural and Geological Report of Mississippi, p. 215.

sand, and are about eight feet from the surface. From Harmon's mill east and northeastward they spread over the country as far as Mr. J. M. Langham's well, on the east side of the J. M. Procella headright. The bluish greensands are found in Mr. Langham's well at a depth of twenty feet, and in a brook two hundred yards south they appear within two feet of the surface. They are also found in great abundance along Saddler creek, on the Anderson county line. From this point southward, through Murchison's prairie, to the crossing on San Pedro creek on the Rusk road, these same greensands occur, and on the south bank of the creek, close to the crossing, the yellow indurated fossiliferous sand forms a bank twenty feet thick. They are also found on the Lewis headright, a mile and a half west of Augusta, and on the Daniel McLean headright, about three miles east of the same place. Large quantities occur in contact with laminated iron ore on the Leonard Williams headright, near Robbin's ferry on the Neches river. In several of the bluffs along the Trinity river, beds of fossiliferous clays and greensands are also found. In Hall's bluff these beds are six feet thick. They occur in Brookfield bluff, and at Alabama crossing the beds aggregate a thickness of fourteen feet. In the stream known as Collin branch, about two miles west of Crockett, a fossiliferous brown sand, ten feet thick, extends southward along the creek from near the Hall's bluff road to the Alabama road, a distance of nearly half a mile.

The following analyses show the composition of the greensands:

No.	Silica.	Alumina.	Ferric Oxide.	Ferrous Oxide.	Lime.	Magnesia.	Carbonic Acid.	Potash.	Soda.	Phosphorous.	Sulphur.	Water and Organic Matter.	Total.
1286	29.40	7.46	5.60	14.54	20.00	2.88	14.80	3.41	Trace	Trace	. . .	2.20	100.29
1302	45.70	18.09	4.00	4.71	8.70	2.00	11.00	4.57	1.20	0.12	Trace	. . . . .	100.09
1449	49.47	24.29	6.76	. . .	1.48	. . .	. . . . . .	0.13	2.17	0.072	1.51	14.17	100.15
1445	47.00	9.78	21.42	. . .	7.58	2.30	undeter.	1.27	4.65	0.56	0.22	undeter.	. . . .
1446	15.30	6.53	39.47	. . .	6.34	5.70	undeter.	0.60	5.15	0.25	0.34	undeter.	. . . .
1447	43.10	13.66	27.54	. . .	1.07	4.76	undeter.	0.56	3.66	0.17	0.25	undeter.	. . . .
1448	30.00	14.11	25.09	. . .	16.80	3.46	undeter.	0.80	4.41	0.44	0.69	undeter.	. . . .
1494	74.90	9.30	5.50	. . .	0.90	0.58	undeter.	1.27	6.67	0.08	0.60	undeter.	. . . .

LOCALITIES.

No. 1286 - K. Jones' well, N. C. Hodges' headright.
No. 1302—Alabama bluff, Trinity river.
No. 1449—Greensand clay, Hurricane bayou.
No. 1445—L. Williams' headright.
No. 1446—Murchison's prairie.
No. 1447—D McLean's headright.
No. 1448—Robbins' well, Leonard Williams' headright.
No. 1494—Hurricane bayou.

The practical utility of these greensands for fertilizing purposes has been partially demonstrated by several of the farmers living in the region in which they abound. These experiments show that lands

treated even with so small a quantity as fifty bushels per acre have yielded an increase in crop sufficiently great to warrant their use.

IRON ORES.

The iron ores of Houston county belong chiefly to the conglomerate variety. Laminated ores occupy a small area in the northeastern portion, and a number of stratified deposits of clay ironstone of varying thickness, occur in connection with the greensand deposits in the central and western portions of the county.

CONGLOMERATE ORES.

The characteristics of these ores have been described by Dr. Penrose in the First Annual Report of the Survey.* In very few particulars, and these trifling ones, do the ores of Houston county vary from those of the other parts of Eastern Texas.† They occur in the shape of detached fields or areas, extending from near the mouth of Hurricane bayou to the northeast corner of the county, near the confluence of the San Pedro creek with the Neches river. The most westerly area lies along the height of the land forming the divide between the waters of the Elkhart creek on the north and Hurricane bayou on the south, and embraces the greater portion of the A. W. Beckham headright, a large portion of the Ramon de la Garza tract, and the whole of the J. W. Hughes, J. Henly, J. Porter, S. B. Langham and J. R. Murchison headrights. They are also found on portions of the A. E. Gossett, J. Walker, W. P. Albert, J. A. Barton and J. L. Walsh headrights. The whole field approximately covers sixteen square miles. The ore is more extensively developed along the eastern side. On the A. E. Gossett land it lies in the form of large bowlders from four to six feet in diameter and from one to two and one-half feet thick. Going westward it becomes more fragmentary and sandy, until near the western limit, on the de la Garza headright, it might also be classified as a ferruginous sandstone.

The central deposit occurs in scattering quantities from Harmon creek, on the southeast corner of the J. M. Box headright, northward as far as the S. W. Stow headright, a distance of nearly six miles. This ore is associated with red ferruginous sandstones, and lies upon a ridge of yellowish gray sand, about two miles wide, underlaid by a red ferruginous sandy clay. The whole area is approxmiately ten square miles. It is of very poor quality, and can scarcely be considered more than a siliceous gravel cemented by a ferruginous matrix.

Southeast of this area, and on the Joseph C. Teague and R. R. Russell headright, there is another deposit mixed with yellow and brown sandstone. This deposit is of no practical value, except that it might, by crushing, form a good road-metal.

*First Annual Report Geological Survey of Texas, p. 81.

†Report on the Iron Ores of East Texas, p. 31.

In the section lying along the Neches river south of the San Pedro creek, and south of the Anderson county line, there lies a deposit of very coarse conglomerate associated with soft red ferruginous sandstones. From the texture it can not be considered as of any practical value for ore purposes.

ANALYSES OF CONGLOMERATE IRON ORES.

No.	Silica.	Alumina.	Ferric Oxide.	Lime.	Sulphuric Acid.	Phosphoric Acid.	Loss.	Total.	Metallic Iron.
1062*	36.75	5.24	51.46	0.82	0.40	0.49	4.90	100.06	36.02
1063*	32.60	4.56	55.04	0.60	0.19	0.20	6.70	99.89	38.53
1064*	37.10	4.09	50.91	1.15	0.47	0.17	6.10	99.99	35.64
1065*	33.92	4.19	54.21	1.00	0.59	0.28	6.10	100.29	37.94
1454	29.20	7.75	48.65	5.60	0.22	0.58	3.60	100.20	34.05
1293†	21.20	. . .	55.40	. . .	. . .	. . .	. . .	. . . .	38.78
1294†	20.60	. . .	53.25	. . .	. . .	. . .	. . .	. . . .	37.27
1295	24.60	. . .	57.39	. . .	. . .	. . .	. . .	. . . .	40.17

*Analyses by J. H. Herndon. †Analyses by L. E. Magnenat.

LOCALITIES.

No. 1062—Twelve miles northeast of Crockett.

No. 1063—Near Davis' creek.

No. 1064—Twelve miles northeast of Crockett.

No. 1065—Eight miles northwest of Crockett.

No. 1293—West side of Hammond creek, J. M. Box survey.

No. 1294—Creek on W. E. Long's farm, south of Old Moorfield, John Beaty headright.

No. 1454—A. E. Gossett headright.

These ores are of no immediate practical value as iron producing materials. Silica is largely in excess, the proportion of metallic iron is below the limit of profitably working ores where charcoal forms the only fuel, and without concentration they would not sustain the cost of transportation to any distance.* They are more or less associated with a brown or dark red ferruginous sandstone, which may be used for some classes of building purposes.

LAMINATED IRON ORES.

In the northeastern portion of the county there is a deposit of ore of the thinly laminated or buff crumbly variety,† covering an area of nearly eight square miles, in the form of a roughly oval shaped field. The southern boundary begins near the southeast corner of the Daniel McLean league and extends as far east as the J. B. Bodan headright. From this place it runs northwestward along the Neches river to within

* For remarks on utilization of this class of iron ores, see Second Annual Report, p. 89.

† See Report on the Iron Ores of East Texas, 1891, p. 28.

a mile and a half of Robbin's ferry, where it changes to a western course through the Leonard Williams and Jacob Prewitt headrights; thence southwesterly, past the northwest corner of the J. Sheridan headright, to McLean creek, and thence southwesterly, through the eastern half of the McLean league, to the southeast corner. The ore is very thinly and irregularly deposited, having a thickness of from only one to six inches. The greater proportion of the ore covering does not exceed four inches.

This field shows the typical bench formation observed everywhere throughout East Texas where this character of material covers the hills. An analysis shows:

Silica	10.20 per cent.
Alumina	9.15 per cent.
Ferric oxide	74.05 per cent.
Metallic iron	51.84 per cent.
Lime	0.15 per cent.
Magnesia	0.10 per cent.
Phosphoric acid	1.35 per cent.
Sulphur	0.11 per cent.
Loss on ignition	4.00 per cent.

One hundred parts of iron contain 1.13 per cent of phosphorus.

CLAY IRONSTONE.

This class of ore is found intermixed and otherwise associated with the greensand marls, and has been observed occupying a position in almost every section in which the marls appear. The deposits, so far as observed, rarely exceed more than six or eight inches in thickness, and generally form lines of partings between the different greensand beds.

Associated with these ores are extensively distributed beds of fossil-bearing siliceous ore, which in some localities reach a thickness of two or three feet, but are usually not more than six inches to one foot. Where a greater thickness than six inches occurs, the deposit is made up of a series of strata each from two to four inches thick.

The localities in which these ores are found in greatest abundance are in the neighborhood of Crockett, where the fossiliferous ore occurs near the Mary Allen Seminary, in a bed one foot thick; five and one half miles west of Crockett, on the Hall's bluff road, the same ore shows a thickness of one foot; but they are best developed in the Hurricane bayou region, where they attain a thickness of from eight inches to three feet. A section of the bank of Flat branch, on the Nevil C. Hodge headright, shows:

1.	Surface material	1 foot.
2.	Dark greenish gray clay	4 feet.
3.	Thin strata of iron ore aggregating	3 feet.
4.	Laminated fossiliferous rusty blue clay	2 feet.

Fossiliferous iron of the same class also occurs at Alabama bluff, where it appears in three distinct strata, separated by deposits of greensand. The beds in the bluff have a thickness of from one to two feet. This class of ores also occurs at various other places throughout the northern and central portions of the county, but are generally very poorly developed.

Clay ironstone occurs more or less connected with these fossiliferous ores. Outcrops are seen on the Rusk and Crockett road, three miles northeast of Crockett, and in both Brookfield and Hall's bluffs on the Trinity river. Small sheets of the same material also occur in the bluffs at Wootters' bluff, on the J. G. Thompson headright, and near Augusta postoffice, where it appears in a bowlder form. The locations and structural conditions of these deposits are shown in the sections under the heading of General Geology.

The analyses of these ores show them to have the following composition:

No.	Silica.	Alumina.	Ferric Oxide.	Ferrous Oxide.	Lime.	Carbonic Acid.	Magnesia.	Sulphur.	Phosphorous.	Loss.	Total.	Metallic Iron.
1290	12.30	5.34	31.70	19.97	3.80	23.20	Trace	0.10	Trace	3.50	99.91	37.56
1291	21.20	. . .	51.40	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . .	35.98
1292	. . . .	. . .	29.39	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . .	20.57
1296	11.50	7.23	34.48	14.12	8.40	12.60	Trace	Trace	Trace	11.70	100.03	35.11
1451	13.10	5.78	57.22	. . . .	5.85	7.40	1.18	0.11	1.22	8.00	99.86	. . .
1493	25.30	6.65	63.95	. . . .	1.15	. . . .	0.10	0.11	3.15	. . . .	100.41	44.76
1457	15.30	7.34	64.26	. . . .	0.74	. . . .	1.08	0.11	0.70	10.60	100.13	44.98

LOCALITIES.

No. 1290—Three and a half miles northeast of Crockett.
No. 1291– Five and a half miles west of Crockett.
No. 1292—Millan branch, west of Crockett.
No. 1296—Near College, Crockett.
No. 1451—K. Jones' farm, Flat branch.
No. 1493—Trinity river. Alabama bluff.
No. 1457—East of Silver creek, near Augusta.

LIGNITES.

Lignite deposits occur at various points. Several of them are exposed in the river and stream channels, and others have been reported as being found at various depths in the digging of wells. The only deposits of any practical value are those found in the southeastern portion of the county, and at Hydes' and Westmoreland's bluffs, on the Trinity river, near the southwestern corner. These have a greater known development than those of any other section, but the analyses of specimens from near Calthorp in the east, and Hydes' bluff in the west, show them to have too great a proportion of ash to admit of their utilization for any other than local or domestic purposes.

ANALYSES OF LIGNITES FROM HOUSTON COUNTY.

	Volatile matter.	Fixed Carbon.	Ash.	Water.	Sulphur.	Total.
No. 1	36.06	32.56	16.70	11.80	0 88	100
No. 2	32 96	22 01	40 03	4.52	0.48	100
No. 3	40.65	30 95	19 75	7 75	0.90	100

LOCALITIES.

No. 1. Hydes' bluff.
No. 2. A. Rice's place, J. Bethed headright.
No. 3. Wallace headright, near Calthorp.

The southwestern field is the extension of a much greater deposit lying in Trinity county to the south. The western limit of the field enters Houston county near the southeastern corner of the W. D. Reed headright on Piney creek, and passes in a generally northern direction a little to the west of Dodsonville postoffice, to the southwest corner of the W. E. Long headright. From this point the line of outcrop turns east as far as Cochino bayou. Crossing the bayou, the eastern boundary, so far as known, extends in a southeasterly direction to and across the county line, on the John Applegate headright. The total area of this field is approximately fourteen square miles. The average thickness of the lignite is from four to six feet, and its quality is shown in analyses Nos. 2 and 3 given above.

In the western part of the field, the lignite, as seen in the four foot deposit on Flat creek, is bright and glossy when first dug, but soon loses its color and become a dull lustreless black, with small, rounded, bright, glossy, bituminous-looking patches or spots scattered sparingly through the mass. It breaks readily into cuboidal blocks, and when dry has a tendency to crumble. On the eastern side of the field, at Rice's, the exposures when dug into show the lignite to have a dull brown color.

In structure this field appears to be slightly trough-shaped, the lignite deposits having an increased thickness toward the centre. A section on the Wallace headright, near the western edge, shows it to have a thickness of four feet, and to be overlaid by a thinly laminated dark colored sandy clay.

Section in Flat creek, J. Wallace headright:

1.	Gray sandy surface soil	1 foot.
2.	Coarse gray sand with occasional deposits of coarse gravel and pebbles	14 feet.
3.	Thinly laminated sandy clays	4½ feet.
4.	Lignite visible	4 feet.

About two hundred yards further west, on the same headright, the lignite forms the bottom of the creek for nearly one hundred feet, and has thinned out to about one foot. It is underlaid by a purple colored

clay, and lies much nearer the surface than where it has a greater thickness. This exposure shows a section of:

1.	Dark gray sandy soil subject to periodical overflow	1 foot.
2.	Gray sand	5 feet.
3.	Laminated clay and sand	4 feet.
4.	Gray sand	3 feet.
5.	Lignite	1 foot.
6.	Purple clay	

The section shown in a stream near Mr. A. Rice's house, on the J. Bethed headright, shows a nearly similar structure:

1.	Yellow gray sandy surface soil	1 foot.
2.	Gray sand with ferruginous pebbles, fine gravel seen in hill	20 feet.
3.	Thinly laminated brown colored clay and sand with interlaminæ of carbonaceous matter	4 feet.
4.	Laminated brown or pink clay	1 foot.
5.	Lignite	4 feet.

Throughout the intermediate region underlaid by the lignite the sections wherever shown are practically the same as those given. The lignite appears in the streams in every place where the cutting is deep enough to reach it, and it is also found in the well borings. On the W. Z. Millen headright it is six feet thick, and lies at a depth of thirty feet. Three miles northeast of the southwest corner of the J. B. Trenery headright it comes up to within eighteen feet of the surface.

The southwestern lignite field is best developed at Hydes' and Westmoreland bluffs, on the Trinity river. At Hydes' bluff the outcrop extends from near the ferry nearly half a mile in a southeasterly direction. The section of bluff shows:

1.	Yellow sandy loam changing into an ashy gray on top, where cultivated	8 feet.
2.	Conglomerate of ferruginous and siliceous pebbles, broken pieces of nodular iron ore, ferruginated and silicified wood and brown sand	2 feet.
3.	Dark blue sandy clay, having one foot of laminated brown sandy clay on top, in contact with the conglomerate, the dark blue clay containing more or less of iron pyrites	10 feet.
4.	Soft lignite, very friable and mixed with sand, in deposition very irregular, and extending from two inches to	2 feet.
5.	Light gray sandy clay, the clay becoming more prevalent towards the base of the bed	10 feet.
6.	Lignite	2 to 6 feet.
7.	Dark purple clay	1½ feet.
8.	Gray sand, containing nodules of sandstone	4 feet.

The lower bed of lignite at this place is very pronounced, and forms a ledge in some places six feet wide along the face of the bluff. In texture, it is strong and solid, of a dark glossy luster when first mined, which it retains for some time, but ultimately becomes a dead black. It breaks in large cuboidal blocks, and disintegrates slowly when ex-

posed to the air. Its composition is very variable, changing materially at different portions of the bed. The analysis given shows it to have 16.70 per cent of ash, but another determination of a specimen not many yards distant showed only seven per cent of ash. It is probable that the lignite from this deposit may, with the good facilities for transportation at hand, be utilized under much the same circumstances as that of the deposit at Alba, Wood county.

A deposit is also reported as existing on the J. A. Miller headright, a short distance north of Knight's creek. Small deposits are reported to exist at other places, but as they have been found in digging wells, no particulars of their structure or condition could be obtained.

BUILDING STONES.

The building stones of Houston county are wholly of sandstone, and belong principally to the Eocene and Miocene divisions of the Tertiary. Some dark red sandstones are found in the overlying Quaternary sands. The Eocene and Miocene sandstones may be divided into two classes, each having characteristics and qualities peculiar to itself, and widely separated from each other. The Eocene are chiefly of an altered glauconitic and ferruginous character, and are frequently only indurated sand, having the peculiar characteristics already described by Dr. Penrose.* Those belonging to the Miocene beds are altogether of a different nature. They are mostly of a whitish gray color, and are generally found bedded, the bedding being from two to four feet. They are also sometimes fossiliferous, in so far that they show broken remains of plant life.

The Quaternary sandstones are red or dark brown in color, soft in texture, and occur only in few places. They are usually found in the shape of aggregations of bowlders, but very often solitary.

Ferruginous sandstones and altered glauconitic sands are found scattered over the greater portion of that division of the county lying north of and at several places within a short distance south of Hurricane bayou. They have been quarried for building purposes at several places, but chiefly at Cook's mountain, about two and one-half miles west of Crockett, and at Hale's quarry on the Sherman headright, about nine miles east of the town.

Cook's mountain, where the quarries are situated, shows an abrupt, almost precipitous face, looking north and northwest, and rising about 130 feet above the level of the lower second bottom lands belonging to Hurricane bayou. No permanent quarries have been opened, and the building stone obtained from this place is taken altogether from the broken debris of the heavy bed of brownish yellow altered glauconitic sandstone forming the cap or covering of the mountain. It contains specks of mica and numerous casts of Eocene fossils, and shows a thick-

*First Annual Report, p. 87.

ness varying from six to ten feet. It is easily obtained, and when freshly quarried very easy to cut and dress. It hardens on exposure to a firm and very durable stone.

The stone found in Hale's quarry is greenish yellow when first taken out, but upon exposure gradually assumes a yellowish brown color. When freshly broken it is very soft, but with its change of color becomes much harder, though still retaining its friable character. It contains numerous mica specks, but so far as observed is non-fossiliferous. This quarry is formed along the face of a ledge looking toward the north, and the rock bed has a face of five feet. This sandstone has been quarried for building purposes at irregular intervals for a great number of years, the principal uses to which it is put being foundations and chimneys.

A deposit of grayish brown sandstone, ten feet thick, also occurs at Brookfield bluff on the Trinity river; and at Hall's bluff, four miles further up the river, there is a bed of sandstone of a very similar character, four feet thick. These sandstones are very friable, and so far as seen can only be classed as indurated sands, and of no value for building purposes.

In the southern portion of the county, the gray sandstones of the Miocene formation occur on the east side of the Chas. Campbell headright, east corner of the J. Gregory headright, the west bank of White Rock creek, on the Francesca Martinez league, and near Pennington, on the Trinity county line.

The deposit on the C. Campbell headright is a small outcropping of about twenty-five acres in extent, and occurs mostly in the form of large bowlders. The stone has a gray color when freshly broken, weathering to a light cream tint. In texture it is compact, siliceous, and contains specks of mica, and occasionally broken remains of plants.

On the John Gregory headright the sandstones exposed lie in regular bedding, and are about fifteen feet thick. The strata are from ten inches to two feet in thickness, and the area occupied by the deposit is from fifty to sixty acres. In texture this sandstone resembles that on the Campbell headright, although its deposition is much more regular.

The deposits on White Rock creek are not confined to Houston county, but extend for several miles into Trinity county. The sandstones outcropping in the higher ground between the creek and its several branches, and along the banks of the main creek itself, are similar in quality and structure to those found on the Gregory headright.

Small quarries have been worked at these three points for several years, and the materials used for building purposes. These sandstones are of close enough texture to admit of dressing, and with the exception of the deposit found on the Campbell headright, can be readily obtained in blocks large enough for any practical purpose. The Camp-

bell deposit, on account of the bowlder like form of the stones, will only supply blocks of a limited size.

Scattered throughout the Quaternary deposits in the northwestern portion of the county, there are numerous aggregations of ferruginous sandstone bowlders, some of which attain a great size. The sandstones belonging to this class are of a brown or dark red color containing small segregations of iron ore and numerous specks of mica. In texture they are coarse grained and soft. They have been utilized by the farmers and others living within the vicinity for building foundations and chimneys.

A deposit of this class of material occurs on the Crockett road about a mile west of Grapeland, and similar deposits occur throughout the region as far west as Elkhart creek.

Brown sandstones of this class occur in great quantities near Hancock's gin, on the A. W. Beckham headright, and along the banks of Coperas creek, in the northeastern portion of the county. In both of these places they are associated with deposits of conglomerate iron ore. Similar deposits associated with conglomerates, also occur on the Stow headright, about twelve miles northeast of Crockett, on the Rusk and Crockett road, and on the J. E. Allen headright, near the Allen school house, about nine miles northeast of Crockett on the same road.

CLAYS.

No good clay, suitable for the manufacture of any of the finer grades of earthenware, have been found in Houston county. Brick clays or earths, in limited quantities, are found among the Quaternary deposits in the northern half of the county, but with the exception of the works at Crockett, no brick making establishment exists. Occasional kilns of brick have been burned at Lovelady and Grapeland, and several other places, but none within the last two or three years. The brick works at Crockett have been in existence during the last three years, and usually employ sixteen hands. The bricks are made from a somewhat gravelly yellowish brown brick loam, found in the immediate vicinity of the Mary Allen Seminary, by a Sword machine having a daily capacity of thirty thousand. These bricks are dried on the yard and require from seven to nine days to burn. When properly burned they are very hard, of a dark brownish gray color, marked with dark blue iron spots. The fuel used is a mixture of oak and pine wood, in the proportions of three-fifths of oak to two-fifths of pine. About one cord of this mixed wood is required to burn one thousand bricks. The average annual output of this yard is between five hundred thousand and six hundred thousand, the statistics of the last three years being: 1889, 1,000,000; 1890, 600,000; 1891, 500,000.

The large number burned during the season of 1889 was due to the contract obtained for the building of the Mary Allen Seminary.

Some of the clays found in association with the upper brown marl beds may possibly be found of a good quality for the manufacture of vitrified paving bricks. An analysis of a clay found in Hurricane bayou bottom lands, on the N. C. Hodges headright, shows it to have the following composition:

Silica	77.70
Alumina	10.37
Iron	9.33
Lime	1.70
Magnesia	Trace
Potash	.24
Soda	.54
	99.78

TIMBER.

Nearly three-fourths of the county is covered with timber. The classes represented are mostly oak, including the several varieties of that timber, pine, hickory and walnut. Gum, ash, elm and other kinds are scattering. The proportions of these timbers appear to be approximately: Oak, thirty-five per cent; pine, thirty per cent; hickory, fifteen per cent; walnut, ten per cent; gum and other trees, ten per cent. The oak is found scattering over the greater portion of the county, and is the prevailing timber throughout the northwest and western areas. The pine, although found in scattering plats near the center of the county, occurs principally in the south and southeastern portions, where it is estimated to yield from eight hundred to ten thousand feet of lumber per acre. It is altogether of the short leaf variety; no long leaf pine grows in Houston county. The hickory is generally found on the bottom and second bottom lands, and the walnut is altogether confined to the second bottom land. These trees are generally scattering. The whole county may probably average from sixteen to twenty-five cords per acre.

From the last assessment rolls there appear to be thirteen saw mills within the county. Some of these, however, have been shut down from various causes.

WATER SUPPLY.

The drainage of the county is divided into eastern, western, and southern basins. The Neches river with its tributary streams, the San Pedro, Hickory and Camp creeks, Cochino bayou, and Piney creek, form the main arteries of the eastern area. The western division is drained by Trinity river with the Big and Little Elkharts, Hurricane bayou, Caney bayou and Negro creek as tributary streams. The southern area, or that of White Rock and Tantabogue creeks, is what may be looked upon as a subsidiary basin tributary to the Trinity river. The divide or water shed between these two areas is chiefly a

series of high land covered throughout most of its course by a light gray sand. Towards the north, the divide extends in an approximately southeast direction as far south as the Luke West headright, about five miles east of Crockett, from which place it divides, the eastern division extending nearly southeast, and separating the White Rock area from that of the Neches. The western ridge between the areas of White Rock creek and the Trinity proper, extends west as far as Crockett, and then bends southerly, a direction it maintains to the county line.

The creeks found in the northern portion of the county form a strong contrast to those in the southern section. In the north, they are strong and active all the year round, and have been utilized as a producer of power for various saw and other mills at one time located along their banks. At present these streams are utilized to drive four mills and gins. The southern creeks are mostly slow and sluggish, meandering through broad bottom lands, subject to extensive overflows in the winter and spring and dry during the summer, or at best containing water only in a few small pools.

Good springs of water occur throughout the northern, and a few in the southern half of the county, but as a general rule the water supply has to be obtained from wells, and that of the southern district is usually of a very poor character, and disagreeable to the taste.

The Neches river is not navigable in any portion of its course bordering on Houston county. The Trinity has been ascended by small steamboats as far north as Green's landing, in Anderson county. Both rivers may, however, be profitably utilized for rafting purposes.

A SECTION

FROM

TERRELL, KAUFMAN COUNTY,

TO

SABINE PASS ON THE GULF OF MEXICO.

BY

WM. KENNEDY.

A SECTION

FROM

TERRELL, KAUFMAN COUNTY,

TO

SABINE PASS ON THE GULF OF MEXICO.

BY WM. KENNEDY.

INTODUCTORY.

In the First Annual Report of this Survey,* Dr. Penrose, Geologist for East Texas, examined the rivers crossing the Tertiary deposits, and described the beds forming the sections shown along the Brazos, Colorado and Rio Grande. The uniform sequence of the various deposits, as exhibited in these river sections, led to the general inference that these, or deposits of a similar character, would be found extending clear across the State, from the Louisiana line on the east to the Rio Grande on the west.

While these river sections are very valuable in many respects, they do not give a consecutive view of the whole of the beds constituting the various divisions of the Tertiary and newer strata in Southern and Eastern Texas. This is necessarily so, as the river banks have not, except at few places, sufficient height to disclose any continuous order of succession of the beds. From the series of bluffs presented here and there, sometimes comparatively close together, but in many cases at long intervals apart on the three rivers mentioned, Dr. Penrose constructed the sections described by him in his preliminary report.

With the twofold object of ascertaining the continuity of the deposits through the region east of Dr. Penrose's Brazos river section, and filling in the breaks necessarily left by him, in order to have as complete a section across the Tertiary areas of the State as could be obtained, I was instructed to run a line southeasterly across these areas from the border of the Cretaceous to the Gulf.

In making such a line of sections, several very important conditions had to be taken into consideration, the most important being the total absence of reliable maps of the region to be traversed. The old maps published by the General Land Office, while useful in many respects, are practically of little or no value for geologic work, and for locating purposes are often very misleading. No roads are shown upon these maps, and nearly every stream is either incorrectly located, or not to

* First Annual Report, Geological Survey of Texas, 1889, pp. 22–58.

be found at all, having an existence only upon these maps. No topographical maps of the region exist with the exception of one single sheet showing the topography of Cherokee county, made by the United States Geological Survey at the request of the State Survey. Until good, reliable topographic maps have been made, any geological work, however careful the observer may be, is liable to inaccuracies, both as to extent and thickness as well as the actual superposition of the beds themselves, and all owing to no fault of the observer. This can be readily understood from the fact that while at one place a deposit of sand may be loose and full of fossil remains, several miles away the sand of the same bed may have become impacted and appear as a soft sandstone containing very few evidences of the rich fauna seen in the loose soft sand, and yet these two may really be a continuation of each other and form the same geological horizon.

A very important consideration was the necessity of having some data as to the relative elevations of the different portions of the country through which the line extended. The levels of the lines of the various railways running towards the coast in the most direct course conformable to the one the sections were wanted, offered the best data obtainable and consequently the line of the section was begun on the border of the Cretaceous area three and a half miles east of Terrell, in Kaufman county, and carried along the following roads:

1. From Terrell to Mineola, along the line of the Texas and Pacific Railway, in a generally east by south course . . . . 46 miles.
2. From Mineola to Tyler, along the International and Great Northern Railway, southerly . . . . 25 miles.
3. From Tyler, southwestward, through Smith, Cherokee and Angelina counties, to Lufkin, along the line of the Tyler Southeastern Railway . . . . 90 miles.
4. From the Angelina river, south, along the Houston, East and West Texas Railway, to Corrigan, in Polk county . . . . 28 miles.
5. From Corrigan, east and southeast, along the Trinity and Sabine Railway, to Colmesneil, in Tyler county . . . . 29 miles.
6. From Rockland, on the Neches river south, along the Southern Pacific Railway, to Sabine Pass . . . . 73 miles.

This gives a total line of sections of 291 miles, in a course more or less in accordance with the general dip of the Tertiary and newer deposits of the State. In addition to the region in the immediate vicinity of the section, many other places were examined, and where possible have been brought into the line.

The results arrived at may be briefly shown in the following table giving the thickness of the different series of deposits. These thicknesses are liable to change in some respects, as more detailed and widely extended examinations of the region progress, but so far as our present knowledge goes may be looked upon as reasonably accurate:

I. Recent material			50 feet.
II. Quaternary—			
1. Sands and gravels		60 feet.	
2. Clays including the Coast Clays		100 feet.	
			160 feet.
III. Miocene (tentatively) Grand Gulf—			
1. Blue limy clays and gray sands containing fossil palm wood, seen at Fleming, in Tyler county		260 feet.	
2. Fayette sands and sandstones		490 feet.	
3. Angelina county beds, laminated blue gypseous clays		100? feet.	
			850 feet.
IV. Eocene equivalent to Timber Belt beds—			
1. Marine deposits, divided into			
a. Upper, or Cook's mountain series	390 feet.		
b. Lower, or Mount Selman series	260 feet.		
		650 feet.	
2. Lignitic deposits—			
a. At Mineola	600 feet.		
b. At Grand Saline	300 feet.		
		900 feet.	
3. Basal Clays, or Wills Point Clay		260 feet.	
			1810 feet.
V. Cretaceous, found in wells at Grand Saline			357 feet.

While the general results of the season's work, and the sequence of deposits in this portion of the State, correspond very nearly with the results arrived at by Dr. Penrose, many beds not seen by him along the rivers have been observed and placed in their true positions. A great many gaps yet remain unfilled, however, and the work of several seasons will be required to bring the various divisions of the general section of the Tertiary areas into close harmony with each other.

The following report has been divided into two sections, showing, first, a general statement of the sequence of the deposits, and second, the details of the examinations made. In an appendix to the second division will be found a table of elevations of the main points along the line of section.

Throughout these details such permanent points as could be found were used as much as possible to locate the different sections. While station houses, switches and ends of sidings have in many places formed these points, the mile posts, being nearly permanent, have been utilized as far as possible, and by reference to their numbering any of the sections can readily and easily be located. In cases where sections were obtained in localities distant from the line of railway, their positions are referred to by the name of the stream on which they are to be found and the headright upon which they are located.

The nomenclature of the beds has been changed so that Dr. Penrose's Basal Clays and the Timber Belt beds are included in the Eocene, while the Miocene may be considered the equivalent of his Fayette beds. The other divisions are included in Dr. Penrose's post-Tertiary deposits.

GENERAL DESCRIPTION.

CRETACEOUS.

After leaving the upper margin of the ponderosa marls at mile post 186, three and a half miles east of Terrell, rocks of the Cretaceous age do not occur anywhere along the line of the section. Indeed it may be said that, with the exception of a few salines of very small areal extent, such as Brooks and Steen salines, in Smith county, and a small saline in Anderson county, no actual exposures of any deposits of the Cretaceous age are as yet known to occur anywhere in that portion of the State east of the Trinity. These salines have already been described in the First and Second Annual Reports of the Survey, and need not be repeated here.

The Cretaceous rocks found at Grand Saline, in Van Zandt county, nowhere, so far as known, approach the surface, but are covered with over 180 feet of Tertiary sands, clays and shaly clays, and are only found in borings of the several wells put down for the purpose of obtaining salt. The upper series of the Cretaceous formation found in these wells appears to be a blue limestone mixed with streaks of sand and gray limestone, having a thickness of 42 feet in the Lone Star well, and 28 feet in the Richardson well, a few feet below which the salt deposit of 300 feet occurs.

While it may be possible that other Cretaceous islands occur in the area traversed by the section, the structural position of those known tends to the hypothesis that they do not, and that, during Cretaceous times, this region formed a triangular bay, of which the widest portion was towards the south. It will be observed from the locations of the islands already known, that the Texas areas have a course slightly west of south, or approximately parallel with the Cretaceous shore line several miles further west, those already laid down on the map of Louisiana, accompanying the Third Annual Report of the Geological Survey of Louisiana,* show a course decidedly from northwest to southeast. These two lines, if prolonged, would converge somewhere near the southeast corner of the Indian Territory, or approximately within the area occupied by the Rocky Comfort Chalks of the Arkansas Survey.

Want of reliable data prevents any theorizing upon the connection between these Cretaceous areas, and numerous observations will yet be required to establish their relationship and true position with regard to the intervening bay-like area in which they do not appear.

*Third Annual Report, Geological Survey of Louisiana. F. V. Hopkins, State Geologist, 1872, p. 203.

EOCENE.

Of the geological series of deposits exhibited in East Texas none of the divisions have the same interest as the Eocene, covering, as it does, an area over one hundred miles in width, and extending from the State line on the east, westward to and beyond the Brazos river, with its great thickness and rich fauna of numerous and beautifully preserved marine shells exhibited in some of the upper beds.

The Eocene deposits are represented in East Texas by three different sets of beds, the uppermost of which are, from their structure and contained fauna, of undoubted marine origin, while the immediately preceding, or the lignitic group, is probably the representative of Hilgard's Northern Lignite, or the Eo-lignitic of Heilprin, and from the numerous deposits of lignite found throughout the beds, and the occasional occurrence of plant remains, must have been either estuarian or marsh during the period of formation. The third and lowermost division, which has been described by Dr. Penrose* as the Basal or Wills Point Clays, and in this report denominated the Basal beds, appear from their structure to be partly, at least, of marine origin, and in all probability represents in some of the beds a marine phase of the northern lignitic. The existence of a twenty foot bed of white limestone containing innumerable casts of *Turritella*, *Cardita* and *Ostrea*, and other marine fossils, mark that portion of these deposits at least as have had a marine origin. These beds may probably be correlated with the Midway or Pine Barren section of the Lignitic in Alabama.†

These deposits do not, so far as known, contain any lignite, but their intimate relations with the lower division of the lignite-bearing strata, and the close proximity of several extensive deposits of lignite, would suggest that at least part of the upper clays of the Basal beds were laid down under very similar conditions to those containing the lignite, and apparently there can be no good reason for making any division between them. They have, however, been kept separate, pending further examination, and the name Basal Clays, or Basal beds, has been retained for stratigraphical purposes.

The three divisions have been described under the headings of:

1. Basal or Wills Point Clays.
2. Lignitic group. } Timber Belt beds.
3. Marine beds. }

1. BASAL OR WILLS POINT CLAYS.

The deposits assigned to the Basal beds of the lower Eocene directly overlies the ponderosa marls of the Upper Cretaceous. Between the two series of deposits, where examined along the contact in Kaufman

*First Annual Report Geological Survey of Texas, 1889, p. 19.

†Bulletin No. 43, United States Geological Survey, p. 70.

county, there appears to be little or no want of conformity, and they are in places so much alike in external appearance that it is difficult to tell where the one ends and the other begins. On close examination the difference is clearly marked by the structure and color of the Tertiary, the lamination of the clays and the sandy partings being more distinct than the laminæ of the underlying marls. The fauna is also different.

Another characteristic is the presence of numerous bowlders of gray limestone containing thin veins or seams of crystalline calcite and fragments of undetermined gastropods. While occasionally occurring in the upper brown clays, the bowlders are mostly imbedded within the gray sands of the formation near the contact of the lower beds with the Cretaceous. In this place they are seen lying in the sands, forming an irregular bed. Numerous similar bowlders also occur in Muddy Cedar creek bottom about half a mile northwest of Elmo station; also east of Elmo on Walnut creek; also imbedded in clay on the Goschen road, two and one-half miles south of Wills Point; and on the south side of Allen creek, four and a half miles southwest of Wills Point, they are found imbedded in a stratified yellow clay similar to that found on a hill near Mrs. Murray's house, about a mile east of Rocky Cedar. In going east from Wills Point the calcareous bowlders imbedded in yellow clay occur at several places scattered over an extent of country nearly two miles in width.

Another feature of the yellow clays is the numerous nodules or concretions of carbonate of lime found in them throughout the whole of the area traversed by the section, as well as in many other places occupied by the thinly laminated brown clays or their accompanying overlying brown sands.

As a general conclusion, it may be stated that the calcareous calcitic bowlders and lime concretions are typical characteristics of these deposits, and from their structure and contained fossil remains appear to have had their source or origin in some bed of Cretaceous deposits not now represented in this portion of the State, and have been deposited since the deposition of the lowermost beds of dark blue laminated and jointed clays.

Interstratified with the clays, and inclosed between the upper brown clay and the lower dark blue division, there occurs a series of beds of white fossiliferous limestone and brown and dark bluish gray sands. These beds show a section of:

1.	White limestone containing numerous casts of shells	8 feet.
2.	Brown sand	2 feet.
3.	Limestone similar to No. 1, but containing a greater number of bivalve shells	10 feet.
4.	Dark bluish gray sand	30 feet.

These limestones and associated sands first appear upon the crest of

the hill about half a mile northwest of the village of Elmo, where the upper limestone forms the surface of the hill for about one hundred yards. Nearer the village the limestones appear in a well digging, and are overlaid by the yellowish brown sand everywhere forming the surface deposit of this region. On going eastward from Elmo the limestones again appear in a tank at Cobb's switch, and about a mile further east, on Rocky Cedar creek, they attain their maximum thickness of twenty feet.

At Prairie Grove postoffice, about two miles north of the railway crossing over Rocky Cedar, the limestones also appear in most of the streams cut in the region, and from their thickness appear to extend much further north.

Somewhere between Rocky Cedar creek and Wills Point these limestones appear to give out, as in a well bored two hundred feet deep they did not appear.

A general section of the beds within the region around Wills Point gives the following:

1.	Yellowish brown sand containing calcareous bowlders of sandstone, limestone with thin veins or seams, occasionally nodules of crystalline calcite, and containing occasional fossil remains	30 feet.
2.	Yellow laminated clay with thin partings of yellow sand and containing occasional bowlders of silicious limestone	90 feet.
3.	Massive bedded clay, showing no signs of lamination, containing numerous bowlders similar to those of No. 1	30 feet.
4.	White limestone containing great quantities of fossil casts, chiefly *Turitella* (?), *Cardita planicosta*, *Ostrea* (?) and other bivalve shells	8 feet.
5.	Brown sand	2 feet.
6.	Limestone similar to No. 4	10 feet.
7.	Bluish gray sand	30 feet.
8.	Dark blue laminated and much jointed clays with thin sandy partings, containing occasional small bivalve shells chiefly, and having a thin pavement of siliceous nodules near its upper surface	62 feet.
9.	Ponderosa marls	....
		262 feet.

The dip of these beds, where traversed by the section, ranges from less than one to nearly five degrees, in a southeast direction.

The greater portion of the area occupied by these deposits consists of prairie with small patches of timber lands interspersed. The timber is mostly blackjack and postoak, with a few black ash and sycamore trees along the creeks.

The economic conditions present no peculiar features. The soils are all suitable for cultivation, although liable to suffer from prolonged dry weather. The clays in many places are suitable for the manufacture of ordinary building bricks, but will probably be found unsuited for any of the finer grades of clay manufacture.

No lignite has as yet been found in any of these deposits, although they occur in many places in the overlying strata.

2. LIGNITIC BEDS.

Immediately succeeding the Basal Clays, and in close contact with them, there lies an extensive series of sands, clays and lignites, having an aggregate thickness of over nine hundred feet.

The western outcrop of these deposits occurs about three miles east of Wills Point, and the deposits themselves extend eastward beyond the Louisiana line. Their northward extension has not yet been determined, but members of the series occur near Springdale, Douglassville and Hughes Springs, in Cass county, Daingerfield, in Morris county, and at Alba, in Wood county. In their southern extension they have been traced through Cass, Marion and Harrison, to the Sabine river. Similar beds also occur in Gregg county, south of Longview, in Upshur county, near Wilkins' mill, and in Smith county, near Tyler.

The sands are variously colored, being white, yellow, brown, red, gray, blue and black, the colors often shading into one another, and with the exception of the dark blue or black, and occasionally white beds, present no uniformity of coloration for any distance. In structure they are laminated or thinly stratified, massive, cross-bedded, and frequently interlaminated with clay. In estimating their dip or thickness no reliance can be placed upon their structure, as the beds occur in all positions and dip at all angles.

The clays occur interstratified and interlaminated with the sands, and in such positions are mostly laminated. Massive and stratified beds also occur in many portions of the area, sometimes nearly free from sand, but the greater portion occur as sandy or micaceous clays. In color they are generally dark blue, gray and black. Occasionally deposits of red and yellow clay occur, and frequently thin beds of white clay are found among the upper members of the series.

The uppermost member of the deposits belonging to this group appears to be a series of laminated or thinly stratified white and red sands and sandy clays, frequently merging into one another and forming a mottled sandy clay or clayey sand. The laminæ generally do not exceed one-fourth to half inch, but the white sandy clay frequently expands to six or more feet. This series is best developed in the neighborhood of Queen City, Cass county, where it has a known thickness of sixty-five feet, for which reason I have called it the Queen City beds. In Marion county, near Jefferson, and in Harrison county the beds appear at various places immediately underlying a yellowish brown sandstone, or altered glauconite, containing occasional casts of fossils, chiefly of the *Cardita planicosta* type. They occur also near Tyler, in Smith county, and as far south as to within two miles of Troupe. Towards the north they occur at Gladewater, in Gregg

county, and from Wilkins' mill, in Upshur county, westward to within a short distance of the Big Sandy.

The lowermost beds of these deposits are not as yet exactly known, but from the records of the several deep wells bored within the area, appear to be dark blue or brown clays. The yellow and brown sands found near the contact with the Basal Clays west of Edgewood do not represent the beds in absolute contact with the underlying Basal Clays, but are probably an overlap of some of the higher deposits belonging to this group. This condition is extremely probable, as towards the southwestern portion of Van Zandt county, and only a distance of two miles or so from the place where the Basal Clays are last seen, lignitic deposits occur in association with blue clay.

Between the Queen City beds and the lowermost deposits of that group there lies a series of black, blue and gray micaceous sands, blue, brown and gray clays, with thin strata of sandstones and limestones, and also containing many small seams and several heavy deposits of lignites, which unfortunately are not visible, or only partially so, at any of the places yet visited.

Towards their southern side the beds belonging to this division present the initial flexing so largely developed throughout the immediately overlying marine or glauconitic beds. These undulations occur at many places south of the Sabine river, in Smith county, beginning a few miles south of Lindale, and extending as far south as Bullard, where the beds pass under the glauconitic sands of the Mount Selman series. From whatever cause this flexing may have arisen, it is evident that the same action involved the structure of these as well as the succeeding beds, although they are widely separated in composition and the conditions under which they were deposited. A striking resemblance between the flexures of the two sets of beds, leading to the conclusion that this bending took place after the upper deposits had been laid down, is their general coincidence with each other and their uniform tendency to a northeast and southwest course, or a course approximately parallel to the old Cretaceous shore-line.

The structure and position of these underlying beds can best be seen in the well sections obtained from different portions of this field, which will be found in the succeeding pages.

1. Lone Star Salt Works well, Grand Saline.
2. Richardson Salt Works well at Grand Saline.
3. Well at Mineola, Wood county.

These deposits so far have yielded no fossils beyond a few broken plant remains found in the stratified bluish sandy clay north of Grand Saline, and whatever may be the ultimate correlation of these deposits, they occupy a position lower than the altered glauconitic fossiliferous sandstones so extensively developed to the south of this region, and

also found as outliers throughout the central portion of Harrison county and higher than the deposits denominated as the Basal Clays by Dr. Penrose.

3. MARINE BEDS.

The succeeding beds in the ascending scale are a group of marine deposits consisting of a series of sands, greensands and clays, having a total thickness of approximately six hundred and fifty feet.

Their areal extent embraces a ridge of land, approximately forty miles in width and having an elevation of from three hundred and fifty to seven hundred feet above tide, extending across the counties of Harrison, Gregg, Rusk, Smith, Cherokee and Houston. They occupy the greater portions of Cherokee and Anderson counties, the whole of the northern half of Houston county, and a great extent of Sabine, Nacogdoches and San Augustine, as well as portions of Smith and Henderson counties. Across the Trinity they extend westward, and in Harrison county, to the northward, they narrow to a point and become more or less broken into isolated hills. Small outliers of the same age are also found at Hughes' Springs and Atlanta and in the northern part of Cass county.

The outlines of these beds have not yet been traced to any extent. They are known to overlie the red and white sands and sandy clays of the Queen City beds in Harrison county, three miles north of Marshall, where they come in direct contact. To the west of Marshall they are again seen overlying the Queen City beds. On the south side of the Sabine river, the brown ferruginous sandstones belonging to the basal division rise thirty feet above the level of the river. Westward, in Smith county, near Bullard, six miles north of Mt. Selman, the base of the series is found in wells at a depth of twenty-four feet, resting upon a black lignitic clay. In Henderson county they occur only in the southeastern portion as iron capped hills. Toward the south, in Houston county, they dip under a series of thinly laminated blue clay and sand containing crystals of selenite; and near Alto, in Cherokee county, the upper beds are overlaid unconformably by a series of black clays and sands containing crystals of gypsum.

The Marine beds may be divided into two groups--the Basal, from its greatest development in Cherokee county, may be called tentatively the "Mount Selman" series, while the uppermost, from its typical development in Houston county, may be denominated the "Cook's Mountain" series.

THE MOUNT SELMAN SERIES.

The beds of the Mount Selman series rise abruptly from the northward to a height of seven hundred feet above sea level, and consist of a series of brown sands, blue clays, greensands, altered greensands, glauconitic sandstone and laminated iron ore, and are more or less fossiliferous throughout.

General section from Jacksonville to Bullard, across the Mount Selman beds:

1.	Gray sand	10 feet.
2.	Brown sand, ferruginous pebbles and iron ore	15 feet.
3.	Mottled sand	10 feet.
4.	Brownish yellow sand	4 feet.
5.	Brown and yellow sandstone	10 feet.
6.	Alternate strata of iron ore and brown sand, the ore in generally laminated deposits of two to ten inches, and sand from one to two feet	8 feet.
7.	Dark greensand containing casts of small bivalve shells	5 feet.
8.	White clayey sand	1 foot.
9.	Dark green nearly black sand, containing thin seams of ferruginous materials near top, and also containing small fish teeth and *Cardita planicosta*	12 feet.
10.	Brown sand	10 feet.
11.	White sand	10 feet.
12.	Alternate strata of brown sand and laminated iron ore, ore generally wavy and not more than two to six inches, and sand one to two feet	20 feet.
13.	Pale blue and brown clay, mottled in places and laminated in others	15 feet.
14.	Alternate strata of altered glauconitic brown sand and iron ore, the ore generally irregularly deposited, laminated and siliceous, and not exceeding six inches to one foot, the sand from six inches to two feet	55 feet.
15.	Brown sand, forming the surface near Bullard, but passing under No. 12 at the base of the hill, altered greensand, changing to yellow a few feet under ground	40 feet.
16.	Dark green sand, containing fossil shells and a few shark teeth	24 feet.
17.	Lignite or "black dirt" having the appearance of drift, containing pieces of wood, leaves, etc.	2 feet.
18.	Dark lignitic clay, jointed in places, and having the joints filled with glossy lignitic material and sand, and said to contain small white shells near the bottom	5 feet.
19.	Brown clay at bottom of well near Bullard, dug into	2 feet.

The minor folds noticed in the beds between Mineola and Tyler are greatly increased in force in the Mount Selman series, and even this mountain, which may be looked upon as being among the highest, if not the highest point in this portion of the country, shows its structure to be that of an elevated synclinal trough. Minor undulations also occur throughout the whole series of the deposits to the southward as far as New Birmingham, and probably further to the southeast than is at present known. So marked are these undulations in connection with the water supply of the region, in many portions of the country underlaid by the beds of this and the succeeding series of greensands, that a knowledge of their structure is of immediate and real service to the inhabitants of the several counties embraced by these beds. It is no uncommon thing, in traveling through this region, to hear the remark

made and the wonder expressed that shallow wells situated upon the tops of the hills contain a never failing supply of water, while those in the valleys and along the hill sides require to be of great depth to insure even a limited quantity. As a general thing the tops of the anticlinals have disappeared through erosion, and many of them are now occupied by the streams of the country.

The causes of this folding are not sufficiently well known, nor have they as yet been examined throughout the whole of the area subject to them with that degree of care which will be required to work out their complete structure. With the partial knowledge now possessed no accurate opinion can be given as to the actual causes that may have induced such an extensive series of folds as have evidently been the means of the elevation of these hills. Whether these folds have been due to an unevenly eroded Cretaceous sea bottom at the time of their deposition, or from other and more remote causes, is not at present known.

The prevalent idea that the changes of dip found in the overlying beds are due to the erosion of the lower sand deposits, through the action of springs and other underground waters, will have to be abandoned. It is undoubtedly true that many of the changes found locally in the neighborhood of the streams are due to this kind of erosion, but some other cause must be found for such an extensive series of undulations as occur in this region, involving as it does two so widely separated sets of deposits as these and the underlying lignite beds. Our present knowledge of the life history of these deposits is extremely meagre. The only fossils so far found consist of a few broken undetermined shells of the *cardita* type, a few casts of a small bivalve, and several small shark teeth.

COOK'S MOUNTAIN SERIES.

The chief characteristics of the upper group of the Marine beds are in many respects lithologically the same as those of the Mount Selman series. They comprise an extensive series of greensands, greensand marls, altered greensand containing thin strata of carbonate of iron, indurated altered fossiliferous greensand, green fossiliferous clays, glauconitic sandstones and clays, stratified black and gray sandy clays, brown fossiliferous sands, and black or yellow clays with limy concretions, with occasional local deposits of black sand with gypsum crystals. The prevailing deposits, however, are the greensands in their several characters. A striking distinction between this series and the underlying Mount Selman is the extensive fauna found in the Cook's Mountain beds.

The general section here given represents the beds of this group from Independence postoffice, in Cherokee county, to Alto, a distance of twenty-five miles. The details of the Houston county series have already been given in the report on the geology of that county.

SECTION—INDEPENDENCE TO DIAL.

1.	Cross-bedded sand with nodules of white clay	5 feet.
2.	Altered greensand containing white nodules, thin streaks of iron ore and casts of fossils	80 feet.
3.	Mottled brown and white sand	2 feet.
4.	Thinly laminated blue sand	6 feet.
5.	Thinly stratified or laminated red and white sand and white clay	6 feet.

SECTION—RUSK PENITENTIARY HILL.

1.	Gray sand	20 feet.
2.	Interstratified laminated ferruginous material, iron ore and altered greensand	40 feet.
3.	Laminated or thinly stratified red and whitish blue sand and sandy clay	20 feet.
4.	Mottled red and blue sandy clay, probably belonging to and forming the lower part of No. 3	25 feet.
5.	Red sand and ferruginous gravel	5 feet.
6.	Brownish stratified sand, mottled in places	60 feet.
7.	Grayish blue stratified sand in creek	3 feet.

NEW BIRMINGHAM SECTION.

1.	Clay	10 feet.
2.	Micaceous sandstone containing iron	3 feet.
3.	Sandstone	8 in.
4.	Micaceous sand	1 foot.
5.	Altered glauconitic containing casts of fossils	6 feet.
6.	Quicksand	1 foot.
7.	Altered glauconite with casts of fossils and thin seam of sandstone near centre	21 feet.

ALTO REGION SECTION.

1.	Gray sand	5 to 20 feet.
2.	Ferruginous sandstone	1 foot.
3.	Iron pyrites and lignite	1½ feet.
4.	Laminated iron ore and brown sand (altered greensand)	10 to 15 feet.
5.	Fossiliferous altered brown glauconitic sand, containing *Anomia ephippioides*, *Ostrea sellæformis*, *Cardita planicosta* and other fossils, and streaks and nodules of calcite	6 feet.
6.	*Yellowish brown and grayish brown indurated glauconitic sand containing *Scutella caput-linensis*, *Gryphæa thyrsæ*, *Ostrea sellæformis* and other fossils	20 feet.
7.	Greensand containing casts of fossils	6 feet.
8.	Brown sandstone, altered glauconite with casts of fossils	30 feet.
9.	Greensand with gasteropods and fish teeth	8 feet.

These beds present in some slight degree the same undulating structure as is seen in the Mount Selman series. This, however, is only seen near the base of the series, and where they come in direct contact with the beds of that division. As they ascend the scale the flexing ceases altogether, or is so slight as not to be appreciable. Toward the southern

*This bed forms a well defined horizon from the Louisiana line westward to beyond the Trinity river.

border these deposits assume a general uniform southeast dip of nearly sixteen feet to the mile. The southern border, so far as has been traced, breaks off somewhat abruptly, and is strongly indented by several great bay-like openings, and probably more than one long, narrow, river-like channel, through and among which the succeeding deposits have been formed in an unconformable manner.

The southern boundary can be easily traced from its entrance into the State in Sabine county, through San Augustine, Nacogdoches, Cherokee and Houston, as far west as the Trinity river, and probably much further, by a heavy bed of grayish brown, changing to a yellowish brown indurated sand, characterized wherever found by the presence of the fossils, *Scutella caput-linensis*, *Gryphæa thyrsæ* and *Ostrea divaricata*. Other fossils occur in this bed, but so far as yet known these appear to belong almost exclusively to it. It is usually about twenty feet thick, and the *Scutella caput-linensis* have not as yet been found in any of the others. The bed immediately overlying this is a brown altered glauconitic sand, with calcitic streaks and nodules containing *Anomia ephippioides* in great quantities, *Ostrea sellæformis*, *Cardita planicosta* and other fossils. This bed occurs at the two places, Alto and Cook's mountain, and at many intermediate points between. It does not, however, exceed a general average thickness of ten feet, being six at Alto and ten in Houston county.

The extensive fauna of this series appears to indicate that it was in part at least a litoral or old sea margin, over which comparatively quiet and not very deep water prevailed. The following is a partial list of the fossils collected at Alto and other places in Cherokee and through Houston county, and identified by Professor Angelo Heilprin. They are all well preserved and in many places are found in abundance.

List of specimens collected in the neighborhood of Alto and McBee's school, Cherokee county:

Gryphæa thyrsæ, Gabb.
Ostrea alabamensis, Lea.
Ostrea divaricata, Lea.
Ostrea sellæformis, Conrad.
Crassatella antestriata, Gabb.
Scutella caput-linensis, Heilprin.
Cardita planicosta, Conrad.
Anomia ephippioides, Gabb.
Cerithium whitfieldi, Heilprin.
Crassatella texana, Heilprin.
Rostellaria lamarckii, Lea.
Arca mississippiensis, Conrad.
Plicatula filamentosa, Conrad.
Pecten deshayesii, Lea.
Fish teeth, several varieties.

Specimens collected six miles southwest of Alto, on the Tillman Waters headright:

Scutella caput-linensis, Heilprin.

Specimens collected in Houston county—

1. At Alabama bluff:

Anomia ephippioides, Gabb.
Natica, ———.
Clavella penrosei, Heilprin.
Plicatula filamentosa, Conrad.
* *Vermetus*(?), undescribed, in great quantities.
Cardita planicosta, Conrad.

2. In Hurricane bayou and near Cook's mountain:

Dentalium, ———(?)
Cardita planicosta, Conrad.
Gryphœa thyrsæ, Gabb.
Anomia ephippioides, Gabb.
Conus sauridens, Conrad.
Cardita tetrica, Conrad.
Natica, ———(?)
Cerithium whitfieldi, Heilprin.
Messalia venusta, Conrad.
Cordiera texana, Conrad.
Pleurotoma denticula, Basterot.
Fusus, ———(?)
Volutalithes dumosa, Conrad.
Plicatula filamentosa, Conrad.
Pyrula, sp. ind.
Pinna, sp. ind.
Clavella penrosei, Heilprin.
Pecten deshayesii, Lea.
Turbinolia, sp. ind.
Ostrea alabamensis, Lea.
Ostrea divaricata, Lea.
Ostrea sellæformis, Conrad.
Shark teeth, several varieties.
* *Vermetus*(?), undescribed, same as at Alabama bluff.

3. Murchison's prairie:

Ostrea alabamensis, Lea.
Cardita tetrica, Conrad.
Cardita planicosta, Conrad.
Rangia, ———(?)
Cerithium whitfieldi, Heilprin.
Crassatella antestriata, Gabb.

MIOCENE.

At the close of the period occupied by the deposition of the last of the Marine beds of the Eocene a break of considerable extent occurred,

*The *Vermetus* (?) found in these beds differs from *Vermicularia bognoriensis* of the London Clay as figured in Prestwich's Geology, Vol. II, figure 177b, and from the *Vermetus rotula* figured by Morton in "Organic Remains of the Ferruginous Sand Formation." American Journal of Science, Vol. XVIII, 1830, plate 3, figure 18. While each of these fossils have four distinct whorls, this has only three. It is smaller, more flattened and has an acute border. The free extremity of the tube tapers to a circular aperture one m.m. in diameter. The two inner whorls are slightly depressed and appear as if they increased in thickness from the centre to the inside edge of the outer whorl. Striations or lines of growth appear on the outer whorl. These striæ are on the free extremity parallel with the aperture, but from the junction with the second whorl bend slightly backward. Two longitudinal ridges extend from the inner whorl forward to the point where the free extremity leaves the last point contact with the second.

The greatest diameter is 10 m.m. and thickness from 2 to 3 m.m. The free extremity projects 5 m.m. beyond the last whorl.

Probably this fossil has already been described in some of the numerous publications referring to the Eocene fauna, but no reference to it can be found in any of the books at present in the library of the Survey or in my own collection.—K.

and extensive erosion appears to have taken place prior to the deposition of the succeeding deposits. Strong proof of this erosion can be seen almost anywhere along the line of contact where the succeeding denudation has carried off the overlying mantle of sand and gravel of the Lafayette formation. This want of conformity is everywhere visible, and the clays and sands of the Grand Gulf deposits are found frequently extending in long narrow strips for several miles into the region occupied by the Eocene marine formations, and at other places abutting bold headlands made up of the deposits of that age.

This group of deposits has been assigned to the Grand Gulf division, and are tentatively considered as of Miocene age, chiefly upon lithological grounds.

These deposits have been divided for convenience of description into three separate divisions:

1. The Lufkin or Angelina county deposits, made up chiefly of dark blue gypseous clays, and gray sands containing quantities of saline matter. These beds also contain lignite, in many places in beds or deposits of considerable extent.

2. The Fayette sands, made up of soft sandstones, light colored clays, sandy clays, and sands with occasional remains of vegetable life. These deposits approach in texture and mode of occurrence the typical Grand Gulf formations, as described by Hilgard as occurring in Mississippi,* and by Hopkins in Louisiana.† The plant remains, such as palms, etc., are also in close correspondence.

3. The Fleming beds consist of heavy deposits of clays of various colors, some of them containing concretions of lime, and gray sands. The plant remains of these sands are chiefly palm wood, and often occur in large pieces and considerable quantities.

LUFKIN OR ANGELINA COUNTY DEPOSITS.

Following the undoubted Eocene of the Cook's Mountain beds, there comes a series of deposits made up chiefly of sands, sandy clays, clays and lignites. The country occupied by them is, as a whole, low and flat, in few places of sufficient relief to present anything but the most superficial section.

In area this group extends from the Angelina river westward and southwestward across the Neches to the Trinity in Houston county. Eastward they probably cross the Angelina, and extend into and even across the southern portion of Nacogdoches, and may also be found west of the Trinity in Leon and Madison counties; but whether they cross the Angelina or Trinity is not as yet known positively. The

*Agriculture and Geology of Mississippi, 1860. p. 147.
Hilgard, American Journal of Science, Vol. XLIII, May, 1892, p. 397.

†First Annual Report Louisiana State Geological Survey, 1869. p. 98.
Second Annual Report Louisiana State Geological Survey, 1870. p. 18.

northern boundary, in the region crossed by the section, begins in Cherokee county, south of Atoi creek, and passes in a generally southwest direction along the margin of the Eocene beds, about two miles south of McBee's school house, two miles south of Alto, and crosses the Neches river a little over three miles to the south of Robbin's ferry. Continuing its southwesterly course as far as Crockett, it bends more to the west for twelve miles, when it again turns south and across the Trinity river at Alabama bluff, where it forms the upper division of the section.

With the exception of only one or two places, the southern line has never been laid down. They are limited to the southward by a series of gray clays and gray sandstones, which occur about a mile south of the Neches, at Clark's crossing on the Houston, East and West Texas Railway, where they rest upon the heavy deposit of gypseous clay belonging to the beds under consideration. The sandstones also occur eastward at Rockland, on the Neches, ten miles north of Colmesneil, and to the westward they have again been crossed at Riverside, on the Trinity; but whether they rest upon the same gypseous clay has not yet been determined, as at neither of these places has the base of the sandstones been seen.

The Lufkin deposits consist of gray, white and blue sands, sometimes laminated and cross-bedded, although the greater portion of them show no structure whatever. They are frequently saline, and in dry weather, the water having evaporated, the pools show heavy incrustations of salt. In many places they contain quantities of silicified wood, forming a strong contrast with the beautifully opalized wood of the succeeding deposits. Quantities of siliceous pebbles occur, at some places in small patches and at others in the form of thin, distinctly formed lines. These pebbles are mostly rounded and water worn, but are occasionally fragmental or angular pieces of an older rounded bowlder. Although they are mostly of quartz or silicified wood, occasional pieces of syenitic rocks have been found scattered through the mass, and many have a thinly stratified or laminated dark blue or black slaty appearance.

The principal bed underlying these sands, and the one probably forming the greater portion of the whole group, is a heavy bed of dark blue changing to a dirty yellow clay, containing clusters of small crystals of gypsum in great profusion. It stretches from the Angelina southward to the Neches, on the south side of which it is seen passing under the gray sandstones of the succeeding group. Where it disappears this bed is thirty-five feet thick.

The basal deposit of this group is a dark blue laminated clay, in the neighborhood of Alto, while in Houston county it consists of a dark blue laminated sandy clay, with partings of brown sand, and containing numerous crystals of selenite. In both cases the clays rest, so far

as can be seen in the sections obtained, directly but unconformably upon beds containing Eocene fossils. Whether these beds are the equivalents of each other can not, with the knowledge at present available, be accurately determined. Their connection may possibly be found in Trinity and the northern part of Polk county, but in the absence of any examinations in these counties nothing definite can be stated.

Another series of deposits which may belong to this group is a set of beds found in the valley to the south of New Birmingham and Rusk, in Cherokee county. These consist of several beds of thinly laminated gray and black sands and gray clay, a section at J. D. Baker's brickyard giving:

1.	Brown sand and gravel with small pieces of gravel and iron . .	2 to 3 feet.
2.	Alternate strata of purplish gray clay and gray sand, the clay in strata of from six inches to one inch, and in places two feet, and the sand from one to six inches. Numerous fragments of leaves occur in this clay	8 feet.
3.	Purple clay containing fragments of leaves	6 inches.
4.	White sand to bottom of pit	2 feet.

These beds do not belong to the Eocene deposits found throughout the higher ground of the country, and may not belong to the group of beds under consideration. They are probably of estuarine or perhaps fresh water origin, but beyond their existence nothing is yet positively known, and they have only been placed in this group tentatively on account of their overlying the Eocene beds in their neighborhood.

Another circumstance which adds to the difficulty of ascertaining the exact geological structure or position of these deposits is the great want of conformity between them and the underlying Eocene beds. Everywhere, where examined, this unconformability is so strong that one is led to the almost unavoidable conclusion that the Eocene had been subjected to a long continued and great erosion before the overlying clays and sands were deposited.

FAYETTE SANDS.

A region of country, extending from the south side of the Neches southward to and beyond Corrigan, and eastward along the Neches as far as Rockland, is occupied by a series of gray sands, sandstones and gray and white clays. Toward the west the sandstones forming the northern boundary of the beds are found near Pennington, in Trinity county, on White Rock creek on the southern line of Houston county, and outlying portions appear near Weldon, in the same county. The southern line extends from the Neches, several miles south of Rockland, westward to and beyond the Trinity, outcrops being found near Summit, in Tyler, Stryker, in Polk, and at Phelps, in Walker county.

Throughout the area the surface of the country is covered chiefly

by a coarse gray sand. The greater proportion of the deposits, where seen, consists of gray sandstones interstratified with gray clays and gray sands, the last containing considerable quantities of opalized wood. A gray sandstone, containing fossil leaves as yet undetermined, occurs about one mile north of Corrigan, and the upper beds of the southern standstones, near Bowers, contain numerous casts of palm leaves, reeds, etc. Some of the palm leaves are of great size, fragments measuring from three to four feet across being of frequent occurrence.

Three miles north of Corrigan, on the line of the Houston, East and West Texas Railway, a deposit of white limestone occurs, containing casts of shells. The fossils found here have been referred to the Eocene by Dr. Dall, on the strength of the existence of the cast of what appears to be a *Cardita planicosta*.

The thickness of these sandstones and clays, as shown by the sections, are approximately one hundred and fifty feet. Near Rockland, they have a thickness of two hundred feet; on the Neches, at Clark's Ferry crossing, thirty feet; the exposures on McManus creek, and other places near Stryker, are over one hundred feet; in Hitchcock's quarry, near Corrigan, twenty feet; and westward, at Riverside, on the Trinity, they appear to have a thickness of over one hundred feet in the river bluffs.

The internal structure of the area, and the actual development of the beds, are not known beyond the few details gathered along the immediate line of the section, which are given in the succeeding pages.

These beds have been referred to the Grand Gulf (Miocene) of Hilgard by Dr. Loughridge,* and denominated the Fayette beds by Dr. Penrose,† and reported as passing clear across the State. In the Second Report of Progress these sandstones have tentatively been placed in the Miocene. The general section across these beds is as follows:

General section from Angelina river, in Angelina county, south, to Corrigan, in Polk county:

1. Coarse gray sand . . . . 50 feet.
2. Laminated blue and white sand . . . . 15 feet.
3. Brownish gray to yellow sandstone, gradually losing its brown tint as it nears the base. The upper brown division is thinly laminated and contains plant impressions and nodules of pure clay. The lower gray division contains clay nodules, but no plants, four feet in railway cut, but fifteen feet in Hitchcock's quarry . . 20 feet.
4. Gray sand . . . . 22 feet.
5. White limestone containing casts of *Venericardia planicosta*(?) and other shells . . . . 2 feet.
6. Indurated gray sand or soft sandstones . . . . 4 feet.
7. Unknown, probably gray sands and sandstones . . . .

* Cotton Production of the Southern States, U. S. Census, Vol. 5, p. 21.

† First Annual Report Geological Survey of Texas, p. 47.

8.	Gray cross-bedded sands	35 feet.
9.	Gray sands with quantities of opalized wood	25 feet.
10.	Laminated pink clay	6 feet.
11.	Gray laminated sand	4 inches.
12.	Gray sand stained brown	1 foot.
13.	Thinly stratified gray sand	1 foot.
14.	Gray sandy clay	3 feet.
15.	Gray sandstone	3 feet.
16.	Shaly gray clay	1 foot.
17.	Gray and yellow sand	3 feet.
18.	Light yellow or cream colored clay	2 feet.
19.	Thinly laminated gray sandstone	3 feet.
20.	Brown laminatad clay	3 feet.
21.	Thinly stratified white and gray sandstone	1 foot.
22.	Gray sandstone stained brown	3 feet.
23.	Thinly stratified or laminated blue clay with gypsum in crystals	35 feet.

FLEMING BEDS.

Succeeding the gray sandstones, sands, and gray or white clays of the Fayette beds, there comes a series of clays and sands or sandy clays.

These deposits are best seen in the neighborhood of Fleming, where, a little west of the station, the Trinity and Sabine Railway line passes over a high hill made up entirely of these deposits. The same clays also occur in a cut on the line of the Southern Pacific Railway about a mile and a half north of Summit station, in Tyler county. How far south these clays and sands extend is not yet known, but in this region the prevailing blue limy clay occurs near Woodville, ten miles south of Colmesneil. This would give that bed a width of at least twelve miles. The clays are dark blue, pale blue, brown, red, yellow, and pale green in color. They occur thinly laminated, or partially stratified, and massive, and have a strong tendency to joint or break into cuboidal blocks with a conchoidal fracture. The most important bed of clay in this group is a blue clay, partially stratified, but showing a tendency to break up into blocks, and containing numerous concretions of carbonate of lime. This clay is perfectly smooth in texture and graduates into the underlying bed of red clay without any break except that of color, and the absence of the limy concretions, which apparently do not occur in the red clay. At least where the beds were examined none were found. The red clay is in every other respect similar to the blue.

Pale green, pale blue and brown clays are found overlying the blue limy clays at the different exposures, but occur most abundantly to the north of Summit station. These colors are not so persistent as the blue, and are probably due to some local cause.

These clays are probably the same as those found by Dr. Penrose and described by him as belonging to the Fayette beds of his Colorado, Brazos and Rio Grande river sections.

These clays in this portion of the State are overlaid by and associated with a series of gray sands, which are mostly coarse grained, sometimes massive, and in localities cross-bedded and stratified. The typical exposure seen at Fleming shows them to be gray stratified sand containing fossil palm in great quantities, with numerous quartz, jasper and other pebbles, and to have at that locality a thickness of twenty feet.

The southern limit of these sands and clays is not yet accurately known, but they appear to be succeeded by the dark blue clays of the Recent, and their estimated thickness is close to two hundred and sixty feet.

General section from Corrigan, in Polk county, eastward, to Colmesneil, in Tyler county:

1.	Brown surface sand	8 feet.
2.	Lenticular deposit of blue clay in cut near Colmesneil	2 feet.
3.	Brown sand	10 feet.
4.	Cross-bedded gray sand	50 feet.
5.	Gray sandy clay	15 feet.
6.	Gray stratified sand containing fossil palm wood in great quantities, with numerous quartz, jasper and other pebbles	20 feet.
7.	Blue clay, partially stratified, but showing a tendency to break up into conchoidal blocks, and containing numerous limy concretions	140 feet.
8.	Red clay, having same structure as No. 7, but without limy concretions	20 feet.
9.	Yellow sand	4 feet.
10.	Gray sandstone	30 feet.
11.	Gray laminated sand or clayey sand	40 feet.
12.	Gray sandstone	140 feet.
13.	Siliceous earth	2 feet.
14.	Blue clay, containing gypsum crystals in pockets	....

General section from Rockland, on the Neches river, in Tyler county, south, to Sabine Pass.

1.	Coastal marshes	12 feet.
2.	Sand seen at Sabine lake	....
3.	Laminated blue clays, extending from Village creek, southward to Grigsby's Bluff, thence to coast, forming sea bottom at seven feet	100 feet.
4.	Brown and gray sands, enclosing pebbles of iron and siliceous rocks, forming the surface as far as Hyatt	60 feet.
5.	Laminated or thinly stratified brown sand with white streaks	30 feet.
6.	Mottled brown with pink shade running through the sand	12 feet.
7.	Mottled blue and brown clay, pale watery green clay, pale brown and blue clays, seen together along small cut north of Summit	70 feet.
8.	Blue clay containing limy concretions	90 feet.
9.	Yellow sand, seen in well at Woodville	14 feet.
10.	Drab colored sandy clay	30 feet.
11.	Gray sandstone, white near surface, but becoming darker towards base, where it is a pale blue	270 feet.

PLEISTOCENE.

The general facies of the Quaternary deposits are orange, brown, red, yellow and gray sands and loams, with occasional deposits of red and yellow clays and silts toward the north, and blue massive and laminated clay in the southeastern part of the State; ferruginous and siliceous gravel; soft, much broken deposits of ferruginous sandstone; broken monolithic bowlders of brown, white and gray sandstone; gravelly and ferruginous conglomerate, and highly siliceous iron ore. The maximum thickness of these deposits has been placed at ninety feet, but this thickness exists at only a few places. As a general rule, the deposits here classed as of Quaternary age are thinly and irregularly deposited, and rarely exceed ten feet in thickness.

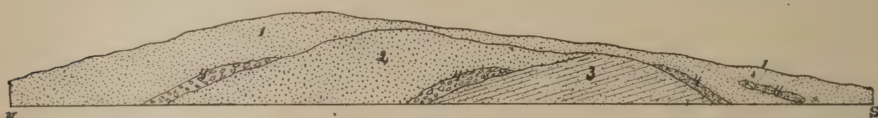

Fig. 3.

Section showing irregular deposition of sand and gravel, mile post 40, T. S. E Ry., Cherokee county Texas.
1. Brown sand. 2. Mottled sand. 3. Stratified sand. 4. Pockets of gravel.

Structurally, these Quaternary sands and gravels show a very irregular deposition, subjected to a variety of vicissitudes In places they present a stratified or quasi-stratified appearance, with regular lines of deposition for short distances, but which soon become broken and irregular. The great mass of the deposits, however, do not present any uniform mode of deposition, but appear as a heterogeneous mass, through which the ferruginous and siliceous pebbles and fine gravels are distributed promiscuously. At places the gravels are deposited in the form of thin strata, extending for many yards and ending abruptly in a deep rounded pothole which they completely fill. Where the iron ore deposits occur the coarser gravels and pebbles show large quantities of ferruginous material, but away from these points the siliceous pebbles and gravels form the prevailing characteristics of the deposit.

In areal distribution it extends from the State line westward to and beyond the Trinity, and from the northern boundary of the Tertiary area to the coast. Ferruginous sands and gravels and siliceous pebbles are found everywhere, capping the highest hills as well as extensive areas of the low lands. In thickness they are very irregular, in some places reaching a maximum of sixty feet, at others not exceeding ten feet, while over wide areas they are extremely thin or do not occur at all. They occur but rarely in the region in which the Basal Clays are found, and their southern limit appears to be near the southern margin of the Fayette beds. Throughout the southern portion of the region occupied by them they appear as outliers or fragmental remains of an

extensive deposit once reaching still further south. The most southerly point at which they have as yet been seen is near Hillester, in Tyler county, within sixty miles of the coast marshes. The section at this place presents a series of yellow, mottled, pink and white, brown and pink sands, with great quantities of ferruginous pebbles scattered throughout the lower division. Ten miles farther south the siliceous pebbles have disappeared, and the last of the ferruginous gravels are seen about a mile north of Hyatt. The yellowish brown sandy loam continues as far south as Village creek, where it disappears under a heavy deposit of pale blue laminated clay. Toward the west, along the east side of the Trinity river, the gravels and sands appear plentifully in Trinity, Houston and Anderson counties. In this region they present the feature of being laid down in long narrow belts extending from the northwest to the southeast.

The gravels belonging to this formation are made up chiefly of ferruginous sandstones and flint, quartz and other siliceous rock. While the greater proportion of them are of white quartz, sometimes perfectly translucent, but oftener stained brown or yellow, many pebbles of dark blue laminated paleozoic rocks occur, and here and there amongst them are found mottled gray and black pebbles and rocks belonging to the quartzitic group. Most of the siliceous pebbles are rounded and water worn. Some few of them are subangular in form, and appear to be fragments of much larger bowlders which had been removed before being broken. Pebbles of silicified wood also occur in great quantities, many of them rounded and perfectly smooth, others flat, smooth sided, from six inches to over a foot in length, and from half an inch to two inches thick. These have their angles scarcely rounded, and present a general appearance of having traveled only a short distance.

The conglomerates belonging to these deposits are altogether made up of ferruginous sands and gravels and siliceous pebbles cemented together by a solution of iron. They have no definite lines of occurrence, but are found usually, if not altogether, in the neighborhood of the streams. The main deposits are always associated with water, and are either close to the high water line or within a few feet of it, and probably had their initial formation with the beginning of the present system of drainage. The older conglomerates are always higher up the side of the hill, and are much harder than the new, so much so, that while the siliceous pebbles in the newer deposits are easily detached from their matrix, they can only be extracted from the older with great difficulty, and break much more readily than they can be detached.

Conglomerates of both these characters occur throughout almost every county east of the Trinity, and as far south as Colmesneil, in Tyler county. In Cass, Marion, Harrison, Gregg, Cherokee and

Houston counties they are extensively developed, and in fact are found more or less throughout the whole of the iron region of East Texas.

Along the Trinity river, in Houston county, the conglomerate is made up chiefly of brown sands, siliceous gravels, broken nodules of iron ore and fragments of a ferruginated fossil wood, and underlies a series of dark gray silty loam, and in structure is much less compact than the conglomerates further north and east.

Another grade of conglomerate occurs in small, scattered, isolated patches crowning the gray sandstone near Bowers and Stryker, in Polk county. This is made up of an association of small grains of translucent or milk white quartz firmly cemented together by a siliceous matrix.

In addition to the pebbles and fragments of silicified wood found in association with the gravels of this formation, great quantities of the same character of wood are found scattered through the sand in almost every portion of the country. Some of these pieces are of great size, ranging in length from four to ten feet, and frequently from six to eighteen inches in diameter. These woods present a variety of structure and color. In most cases they are gray or brownish gray, and many of the brown blocks have black streaks running through them. Pieces showing these colors have their general woody structure still visible, and from their general occurrence throughout the gray sands, upon which grows a dense growth of postoak and blackjack, and the general resemblance of the silicified pieces to these woods, have given rise to the opinion prevailing among the people that these fossil woods are of the same class of timber.

Fossil wood also occurs in the lignite beds and sand. In these, however, the structure of the wood is mostly destroyed, and the color, even when perfectly silicified, is always a black or a very dark blue.

With the exception of the silicified wood in the gray and brown sand, no fossils of any kind have yet been found.

The origin of the gravels has not been determined, but it is more than probable that the greater portion of them are of comparatively local derivation, having originated in some of the paleozoic rocks, occupying the country towards the north and east. Any of more distant origin have evidently came into the region by a process of reassortment due to the action of the water.

In the southern portion of the State, through Hardin county, the Quaternary appears to be represented by a series of dark blue, massive, laminated clays, of which, however, very little is yet known. They are first seen on the south side of Village creek, in Hardin county, and extend southward as far Grigsby's bluff, when they are lost under the coast marshes. They also occur along the coast around the entrance of Sabine lake, forming the sea bottom.

The clays are usually dark blue in color, but in places are massive

and a light blue with slightly yellow shade. In most places they appear as laminated, or thinly stratified. Towards their northern end, however, and in the neighborhood of Concord, on Pine Island bayou, they appear as massive. Owing to the prairie-like region embraced by these deposits, and the few breaks found anywhere within their area, no good sections are obtainable. The streams where any do exist are usually bordered by marshy land, and even there no opportunity is afforded to see much, if anything, of their structure. They have been classed as of Quaternary age, and probably may be correlated to the Port Hudson of Hilgard. Their thickness will probably not exceed one hundred feet.

RECENT DEPOSITS.

Deposits of Recent material are extensively distributed throughout the whole of East Texas. Most of the rivers and their larger tributary streams are subject to extreme variations between high and low water marks. As a result, there are extensive areas of overflow lands everywhere along the water-courses. Occasional bluffs occur of sufficient elevation to stand above the high-water mark, but in many places the overflows reach depths varying from a few feet to twenty-five or thirty feet, and in some extreme instances the water has risen to forty-five feet.

In addition to the Recent deposits of the flood plains of the rivers and creeks, the low lying coastal plain bordering the inlets of Sabine lake and Galveston bay and other portions of the Gulf coast is altogether of Recent origin.

A third series of Recent deposits are to be found in the numerous lacustrine formations occurring at many places. These deposits are, however, generally of small extent areally, and so far as our present knowledge goes, badly defined. In places they are represented by small marshy deposits, and at others by small prairie-like spots, deriving the material for their formation from the surrounding area belonging to the older deposits.

Areally, the only deposits of Recent origin of which any real or accurate knowledge is at present available are the flood plains of the rivers and creeks or bayous and the great coastal plain, and to these only has any direct attention been paid.

FLOOD PLAINS OF RIVERS.

Nearly every river and large stream, as well as many of the minor tributaries, are bordered along each bank by extensive flood plains, or lands subject to periodical overflows. A characteristic common to most of the rivers, where broad flood plains exist, is the tendency of the main streams to change their courses, sometimes rapidly and in other cases very slowly.

Where cut-offs occur, the old course of the river can readily be traced by a line of deep pools connected by shallow marshy places. Instances of this class occur on the south side of Sulphur Fork, in the northern portion of Cass county, and along the Sabine river through the southern portion of Harrison county, as well as at other places throughout the region drained by these streams. The Sabine appears to have had many changes of this character within a comparatively recent period. Where the Texas and Pacific Railway crosses, on the west side of Wood county, a well defined channel appears running parallel to the present course of the river, with which it is connected at its northern end by a series of small pools or lakes lying within the limit of the flood plain; and near the crossing of the Mineola division of the International and Great Northern Railroad, another chain of small marshy pools, lying nearly a mile and a half north of the present channel, again marks the old course of the stream.

Of the slower changes of the stream courses the only evidences noticeable are the general destruction and disintegration of the lower deposits, while the upper beds, still subject to overflow, present the laminated appearance found everywhere. Extended areas of this class of deposits occur along the Sulphur, Sabine, Neches, Angelina and Trinity rivers.

At the crossing of the Sabine by the Texas and Pacific Railway, near Silver lake, the flood plain of the river is nearly half a mile wide, and where the Mineola branch of the International and Great Northern Railroad crosses, the flood plain lying north of the river is over two miles in width. In Gregg county the width of the overflow lands is contracted to small areas lying alternately on each side of the river. In Harrison county the flood plain again widens out and covers an area of nearly a mile in width across the greater portion of the county. Where the Houston, East and West Texas Railroad crosses the Neches, the flood plain is nearly a mile and a half wide, and north of this, on the same railroad, at the crossing of the Angelina, there is another extensive erea. Along the Neches river, on the western portion of Henderson county, there is an extensive area covered by Recent deposits, and throughout Houston county the Trinity river, in wet seasons, overflows its banks in many places to a width of several miles. Along the smaller bayous and creeks tributary to these larger streams the same conditions exist.

COASTAL PRAIRIES OR PLAINS.

The Gulf coast along East Texas is occupied by an extensive prairie or plain, in many places cut by bayous and occupied by extensive marshes, and in no place except the region of High Islands, about fifteen miles east of the eastern extremity of East bay, elevated more

than a few feet above the level of the waters of the Gulf and Sabine lake.

"From the head of East bay to High Islands the land is low wet prairie, covered with ponds, and in many places impassable for wagons. The High Islands are the only high lands on the Gulf coast between Galveston and Sabine, and probably the highest on the coast of Texas. Their elevation is eighty to one hundred and fifty feet above high water, and their area about two thousand acres. The central point of the islands is about a mile and quarter from the Gulf shore.

"From the High Islands to the Sabine all is prairie, in some places impassable marsh to a breadth of seven miles in the wet season, small bayous running through in various directions and entering the lake or ponds. Firm land at all seasons can not be found short of from six to nine miles from the coast, and in many places not short of fifteen or twenty miles.

"In very violent southerly winds nearly all the prairie for some distance back to the shore is covered by water from the Gulf."*

Beginning near Beaumont, in Jefferson county, a belt of Recent material nearly a mile wide, mostly marsh and subject to overflow, extends southward along the west bank of Snow river as far as Grigsby's bluff, where it broadens out along both sides of the river. From Grigsby's bluff this belt of low land widens westward, its approximate line of contact with the underlying blue clay being a line running westward and southward crossing Hillebrand's bayou near the junction of Point bayou on the C. Hillebrand headright.

The country lying between this boundary line and the Gulf coast presents most of the features described by Bell as given above. It is low and flat, much cut up by bayous and ponds, with numerous marshes, and in many places absolutely impassable for wagons. It is altogether devoid of trees, and is covered throughout its greatest extent by a heavy growth of coarse marsh grasses.

Taylor's bayou, with its tributaries, Mayhew bayou, North fork of Taylor, and Bayou Din, and Double Point, Hillebrand and Beddie's bayous form the principal water courses along the northern and central portion, and Texas bayou in the extreme southeastern section.

From the nature of the country no sections could be obtained in any portion. Its structure appears, from a surface examination, to be chiefly a sandy ridge along the Gulf coast, slightly elevated above the back country, which, as already stated, is to a great extent made up of or covered by marsh. The depth of this marsh is probably not very great, and may only be a surface formation resting upon the dark blue clay outcropping near Spindle Top, about four miles south of Beaumont. These blue clays, according to the observations of the United States Coast Survey, appear in Sabine pass and along the Gulf coast

*Lieutenant GeorgeBell, United States Coast Survey, 1861, p. 264.

at a depth of only six or seven feet, and are also found about two and a half miles north of the entrance to the Pass at a depth of twelve feet.*

From Beaumont to Sabine Pass the distance is about thirty miles, and these clays disappear about six miles south of Beaumont, or at an elevation of about twenty feet above tide level. This would give the clay, assuming the upper bed at both places to be the same, a dip of about one foot per mile, and give the marsh an average thickness of twelve feet.

Grigsby's bluff forms a prominent feature along the Neches river, about four miles north of the entrance of the stream in the Sabine Lake. The bluff itself is made up chiefly of Recent material. It is about one hundred and fifty yards long and from ten to fifteen feet high. The main feature is the presence of shells of the *Gnathadon cuneatus* in vast quantities, mingled with vegetable molds, and having a few scattering shells of an oyster associated with the Gnathadon forms. Similar shells and moulds occur at several other places along the Neches as far up as Beaumont.

LACUSTRINE FORMATIONS.

Scattered through this portion of the State numerous small prairie-like spots occur. They usually lie in depressions, and have the appearance of having been marshy lands which have been filled up by the washings of the surrounding higher ground within comparatively recent times. The gravel and other deposit belonging to the drift formation are usually absent in these locations, or if present at all are covered by a heavy deposit of dark gray sand or silty loam, and are always secondary in importance to the overlying material.

These prairies are for the greater part treeless, but within recent years long narrow strips of woodland have begun to stretch their finger like shapes far into and in places quite across the prairie, and the surrounding timber is also gradually narrowing the limits of the treeless space.

These deposits have not yet been studied, and with the exception of those found in Houston county, and described in the report on that region, nothing accurate is known about them.

* United States Coast and Geodetic Survey, 1883, p. 176, sketch 1[2] in same volume.

DETAILS OF SECTION.

The line of section has been separated into six divisions corresponding to the different railways along which it extends.

1. FROM TERRELL TO MINEOLA, ALONG THE TEXAS AND PACIFIC RAILWAY.

This line of sections runs in a nearly east and west course, while the dip of the various beds passed across are within a few degrees of southeast.

From Terrell eastward, to within a few miles of the village of Elmo, the country is comparatively level and covered with the yellow clayey marls of the Ponderosa beds of the Upper Cretaceous.

At mile post 186, or three and one-half miles east of Terrell, the marls are overlaid by a series of thinly laminated dark blue or almost black sandy clays and sands, containing in many places small broken Tertiary fossils. These are altogether bivalves, and are in such a condition that it is difficult to recognize them. No fossils occur close to the line of contact, but are found in a cut one mile further east, where they are associated with a thin line of small calcareous nodules.

The clays are overlaid by a deposit of brownish gray sands containing numerous calcareous bowlders mixed through the sands, and which are occasionally fossiliferous, containing fragments of gasteropods.

A cut on the railway at the line of contact shows the following section:

1. Brownish gray sands containing bowlders of limestone with thin seams of crystalline calcite and occasional broken gasteropod shells . . . . 25 feet.
2. Thinly laminated dark blue clays with broken bivalve shells in places and occasional nodules of siliceous limestone . . . . . . 30 feet.
3. Yellow Ponderosa marls . . . .

Going eastward from this place to Elmo the gray sands and clays of the above section are seen near Muddy Cedar creek. Half a mile north of the road the same class of calcareous bowlders are found forming the bed of the creek, and the same dark clays form the base of the material seen on Walnut creek half a mile east of Elmo station, at which place they are overlaid by a grayish brown sand enclosing bowlders of limestone of the same character as those found in the sands west of Elmo.

About a half mile northwest of Elmo station there is a hill a section of which gives:

1. Yellow sand . . . . 4 feet.
2. White limestone containing *Turritella*, *Cardita planicosta*, *Cardium* and *Ostrea* (?) . . . . 6 feet.
3. Brown sand parting . . . . 2 feet.
4. White limestone containing shells same as No. 2 . . . . 2 feet.
5. Bluish gray sand . . . . 8 feet.

A short distance east, the limestone is covered by a yellow sand.

This is the first occurrence of the white Turritella limestone in the area, and its position, as will be seen from the above section, is not as has hitherto been supposed at the base of the Tertiary deposits in this portion of the State, but at least fifty feet above the base.

Four miles east of this section a tank at Cobb's switch shows a section of:

1.	Brownish yellow sand	12 feet.
2.	White limestone, with brown sandy parting	10 feet.
3.	Gray sand to bottom	

One mile east of Cobb's switch the white limestone occurs in the bottom of Rocky Cedar creek, and at the crossing of the public road to Wills Point, about a mile south of the line, the limestone is twenty feet in thickness.

In speaking of this locality, Mr. R. T. Hill says (Vol. 2, Geological Survey of Arkansas, 1888, page 56): "A similar non-conformity between the Basal Tertiary and the Upper Cretaceous is also well shown four miles east of Elmo in Texas." Mr. Hill is probably mistaken in his locality, as at Rocky Cedar, four miles east of Elmo, the Tertiary deposits are at least fifty feet thick. The bed exposed in the creek, for nearly two miles north of the railway and about a mile south of the same place, is the white Turritella limestone, and is over twenty feet in thickness, of which the upper surface only is seen near the railway and public road crossing.

From this it will be seen that these limestone deposits have a tendency to thicken towards the southeast. Whether they reach their maximum thickness a little east of Rocky Cedar is not known, but apparently they thin out after passing this point, as the limestone was not seen in a well bored two hundred feet deep in Wills Point, five miles further east.

From Rocky Cedar, going east, the line of section extends across a series of yellow laminated clays and clayey sands, having a uniform southeasterly dip of from two to five degrees. These clays close to Wills Point contain occasional calcareous bowlders and nodules, which become more plentiful toward the south and southwest. They occur half a mile south of Wills Point, on the Goshen road, and also four miles southwest on the Allen headright on the south side of Allen creek, where they lie imbedded in a yellow stratified clay, which clay forms a subsoil and underlies the prairie as far east as mile post 171, or three miles east of Wills Point.

From the contact of the laminated blue clays with the Ponderosa marls, three miles west of Elmo, to the point of the disappearance of the yellow clay, three miles east of Wills Point, the width area embraced by the Basal Clays of the Tertiary deposits in this portion of the State is fifteen miles, and the complete section of these clays and sands show them to have a total thickness of two hundred and sixty-two feet.

The country which they occupy is characterized by extensive prairies interspersed with small patches of timber, mostly post oak and black jack with a few black ash and sycamores along the creeks.

Near mile post 171 the character of the beds change from clay to gray and brown sand, and four hundred feet west of the mile post the overlying deposits are sandy clays and sand containing great quantities of ferruginous sandstone nodules, and sixteen hundred feet east of the mile post a section gives:

1. Coffee colored sandy soil mixed with ferruginous pebbles . . . . . 3 feet.
2. Yellow sandy clay . . . . 2 feet.
3. Ferruginous sandstone, with small lenticular nodules of clay ironstone . . . . 6 inches.
4. Finely laminated yellow sand . . . . 4 feet.

These beds dip southeast at an angle of two to three degrees. This change in the deposits is marked by the first occurrence of timber in any extensive body.

Going eastward, towards Edgewood, the overlying sands thicken rapidly. Near mile post 168 a section of the cut shows:

1. Yellow sand . . . . 12 feet.
2. Fine grained yellow clayey sand, visible . . . . 2 feet.

Near the east end of the cut the sand has been eroded, and a deposit of coarse sand or gravel occurs in the shape of a pothole fifty feet long and from one to eight feet in thickness. This cut lies on the west side of a creek having a bottom or flood plain three thousand feet wide.

The sand on the east side of the creek shows a thickness of fourteen feet, and at Edgewood station a cut shows sixteen feet. Wells dug in the vicinity of Edgewood, however, give this sand a much greater thickness. A well close to the station gives the following section:

1. Yellow sand . . . . 16 feet.
2. Blue sand . . . . 40 feet.

Another well near this place struck lignite at thirty feet, and a well dug about a mile east of the station gave the following:

1. Yellow and blue sand . . . . 40 feet.
2. Lignite . . . . 4 feet.
3. Sand, color not stated . . . . 36 feet.

Going eastward, from Edgewood, the yellow sands continue to form the surface deposits. A few fragments of silicified wood and nodules of iron ore occur near Stevenson switch, and eastward of this place there is a small deposit of rounded and water worn gray sandstone enclosed in a deposit of gray sandy clay. The gray clay is replaced, six hundred feet toward the east, by brown sand more than twenty feet in thickness. Near mile post 165 the railway passes through a cut showing a section of:

1.	Soil	1 foot.
2.	Brown sand	2 feet.
3.	Gray sand, stained brown on the outside	12 feet.
4.	Blue clay, seen at the west end of the section	4 feet.

The dip of the underlying clay in this section is south of east a few degrees, and between the brown sand, No. 2, and the gray sand, No. 3 of the section, there occur a few bowlders of ferruginous sandstone and a small quantity of iron ore.

At the eastern end of this cut the deposits underlying this blue clay are shown in the following section:

4.	Blue clay, as above	4 feet.
5.	Yellow sand	2 feet.
6.	Ferruginous sandstone	2 feet.
7.	Stratified blue clay, containing small particles of lignitic matter divided by a thin yellow sandy parting, visible	2 feet.

About a mile further east the cut gives the following section:

1.	Surface soil	1 foot.
2.	Brown sand with ferruginous gravel	$2\frac{1}{2}$ to 3 feet.
3.	Laminated bluish sand and clay	2 feet.
4.	Same as No. 3, but containing deposits of gravel	$1\frac{1}{2}$ feet.
5.	Laminated sand and clay, the sand light grayish blue, clay dark blue	6 feet.
6.	Gray cross-bedded sand	$1\frac{1}{2}$ to $2\frac{1}{2}$ feet.
7.	Laminated blue clay with sandy partings	$1\frac{1}{2}$ feet.
8.	Bluish gray sand	$2\frac{1}{2}$ feet.

The general dip of these beds is southeast two degrees.

Crossing Crooked creek, a hill to the east of the creek shows a section of:

1.	Surface soil	1 foot.
2.	Reddish brown sand, becoming cross-bedded a short distance east	10 feet.
3.	Massive unstratified yellowish gray sands, nearly white in places	15 feet.

Fifteen hundred feet east of this cut the brown sand, No. 2, is overlaid by thinly stratified white sand dipping south twenty degrees east at an angle of four degrees.

A compiled section of this part of the line gives:

1.	Surface soil and brown sand	$2\frac{1}{2}$ feet.
2.	Ferruginous sandstone	$1\frac{1}{6}$ feet.
3.	Dark brown iron-stained sand, wedge-shaped, from	6 in. to 3 feet.
4.	Stratified white sand	4 feet.
5.	Cross-bedded brown sand	10 feet.
6.	Unstratified yellow sand	15 feet.

On the old Dallas and Shreveport road, at Devil's Gap, about half a mile south of the line, a cut in the road shows a section of:

1.	Brown sand and ferruginous gravel capping the hills in the neighborhood	20 to 50 feet.
2.	Stratum of ferruginous sandstone	8 inches.

3.	Interstratified deposits of brown sand and clay in thin strata from	½ to 2 inches.
4.	Blue sand	...
5.	Blue clay	...

The peculiarly protective action of the hard cap rock overlying a deposit of soft material is beautifully illustrated in the case of the eight inch stratum of sandstone a few hundred yards east of the last section near the west side of Mill creek. In a cut on the road the sandstone is broken in places, but where it remains the thin slabs of stone are seen resting upon pedestals of underlying sands and clays. These stand out very prominently from the face of the cut, and are frequently completely isolated from the bank. These pillars are of a uniform height of five feet, and their former connection with the bank behind them can be traced by the thin band of sandstone passing towards the east around the hill.

Crossing Mill creek, and going east, the country is covered with the gray sand streaked and cross-bedded and lying in strata of unequal thickness for nearly a mile. Near Bolton's switch a cut in the hill shows the section of:

1.	Ferruginous material and sand	2 feet.
2.	Stratified gray sand	2 feet.
3.	Thin stratum of ferruginous material	½ inch.
4.	Stratified blue clay	5 feet.
5.	Thin stratum of brown sandy lignite	1 foot.
6.	Blue clay	3 feet.
7.	Stratified bluish colored sand	6 feet.

The lower beds of this section dip three degrees to the southeast.

Going eastward the sands and clays seen in the following section maintain a southeasterly dip of two to three degrees for nearly a mile, after which they change slowly to a northwestern direction:

1.	Surface soil	1 foot.
2.	Brown sand and sandy clay	2 feet.
3.	Blue clay	6 feet.

On the east side of Caney creek, a cut or washout nearly six hundred feet long, and from fifteen to twenty feet deep, shows a series of gray and brown cross-bedded sands which are apparently underlaid by the blue clay found west of the creek. The cut shows the following section:

1.	Soil	10 inches.
2.	Brown cross-bedded sand	2 feet.
3.	Brown stratified sand	2 feet.
4.	Grayish blue sandy clay, showing a rolling structure dipping west two to four degrees	4 feet.
5.	Gray sand	3 feet.
6.	Interlaminated sand and clay	15 to 18 feet.

The thickness of the brown, overlying sand in this region is some-

what variable, as a well two hundred yards north of the road gives a section of:

1.	Brown sand	38 feet.
2.	Black (slaty ?) laminated clay	4 feet.
3.	Gray sand	10 feet.

Eight hundred feet east the section is:

1.	Brown sand	5 feet.
2.	Stratified gray and brown sand	3 feet.

These sands dip southeast, but three thousand feet further east the section shows the same beds dipping in a northwesterly direction. The section is as follows:

1.	Brown sand	4 feet.
2.	Gray sand with ferruginous materials	8 feet.
3.	White sand	

The dip of these beds is extremely variable, although from this last section uniformly towards the northwest.

GRAND SALINE REGION.

The region around Grand Saline is a region of much disturbed strata. The Saline itself is a small prairie-like sandy plain, the sands of which are strongly impregnated with saline material and underlaid by comparatively level deposits.

On the west and northwest sides of the Saline the country rises for several miles, and then descends toward Caney creek and the Sabine river. In this region the deposits are made up chiefly of clays, sandy clays and sands, with several thin beds of soft bluish yellow and blue limestone. Associated with the lowermost stratum of the limestone seam there appears to be a thin stratum of quartz. The lowermost of these beds dip at very high angles, but show a gradual decrease in declivity toward the west or uppermost deposits in the series. Towards the southwest side of the Saline the beds have the same strike and dip, but are mostly covered by deposits of the Quaternary period. To the northeast and east the deposits seem to have generally a low dip toward the east and southeast.

The structure of the prairie is best exhibited by the borings of the wells made for the purpose of obtaining salt from the underlying deposit. A section of the Lone Star well, close to the Grand Saline station, gives:

		Thickness.	Depth.
1.	Brownish gray sandy clay	26 feet.	26 feet.
2.	Brown sand	8 feet.	34 feet.
3.	Sand and gravel	3 feet.	37 feet.
4.	Black shaly clay	20 feet.	57 feet.
5.	Lignite	3 feet.	60 feet.
6.	Sandy shaly clay	20 feet.	80 feet.
7.	Sand and water	5 feet.	85 feet.

8.	Sandy clay shale	65 feet.	150 feet.
9.	Sand and water	14 feet.	164 feet.
10.	Hard white sand with a vein of salt water, five per cent salt	14 feet.	178 feet.
11.	Hard sand rock	6 feet.	184 feet.
12.	Shale containing pyrites	4 feet.	188 feet.
13.	Blue limestone mixed with streaks of sand and gray limestone, but blue forming chief deposit	42 feet.	230 feet.
14.	Gypsum	5 feet.	235 feet.
15.	Rock salt	124 feet.	359 feet.

This well commences in a brownish gray sandy deposit lying along the western side of the prairie, and the elevation of the mouth is nearly thirty feet above the mouth of the Richardson well.

The Richardson well has been bored in the prairie close to the western side, and gives the following section:

		Thickness.	Depth.
1.	Soil, brownish black sand	3 feet.	3 feet.
2.	Sandy clay	12 feet.	15 feet.
3.	Gravel and clay	5 feet.	20 feet.
4.	Yellow sand and water	6 feet.	26 feet.
5.	Fine blue clay and gravel	2 feet.	28 feet.
6.	Quicksand with water	2 feet.	30 feet.
7.	Coarse white sand	5 feet.	35 feet.
8.	Blue gray merging into bluish black dirt with iron pyrites and broken limestone	48 feet.	83 feet.
9.	Hard gray limestone	3 feet.	86 feet.
10.	Sandy shaly clay, (slate?)	17 feet.	103 feet.
11.	Blue clay with iron pyrites	20 feet.	123 feet.
12.	Shales?	9 feet.	132 feet.
13.	Shale with iron pyrites	5 feet.	137 feet.
14.	Sandy shale with pyrites	12 feet.	149 feet.
15.	Sandstone with pyrites	14 feet.	163 feet.
16.	Hard blue limestone	25 feet.	188 feet.
17.	Hard gray limestone	3½ feet.	191½ feet.
18.	Quicksand	2½ feet.	194 feet.
19.	Alternate strata of salt and limestone	18 feet.	212 feet.
20.	Rock salt	300 feet.	512 feet.
21.	Bluish gray sand	2 feet.	514 feet.
22.	Black sand with water, in bottom of well not bored through	6 feet.	520 feet.

These two wells are about half a mile apart, and the line between them extends due east and west. On the south side of the prairie, and due south of the Richardson well, another boring entered the rock salt deposit at three hundred and thirty-five feet. The section of this well is said to be the same as the Richardson, but no accurate particulars could be obtained.

From these borings it would appear that the deposits filling the prairie-like depression are comparatively level.

The basal section of the deposit lying northwest and west of the Saline are shown in the following section:

1.	Upper surface of brown and gray sands having no definite lines of stratification on top of hill	10 feet.
2.	Soft limestone, dipping 70 degrees north 10 degrees west	1 foot.
3.	Bluish gray sandy clay with white limy concretions	49 feet.
4.	Soft yellowish blue limestone, same as No. 2	1 foot.
5.	Gray sandy clay, covered in places by ferruginous sand	91 feet.
6.	Ferruginous clay	½ foot.
7.	Gray sandy clay containing small streaks of ferruginous nodules, highest streak nine feet from upper surface	40 feet.
8.	Soft bluish limestone, dipping 70 degrees north 10 degrees west	¾ foot.
9.	Gray laminated sandy clay	2 feet 2 inches.
10.	Indurated ferruginous sandy clay	4 feet 2 inches.
11.	Gray laminated sandy clay	4 feet 2 inches.
12.	Indurated ferruginous sandy clay	½ foot.
13.	Laminated gray sandy clay	3 feet.
14.	Indurated ferruginous sandy clay	½ foot.
15.	Laminated gray sandy clay	4½ feet.
16.	Indurated laminated sandy clay	½ foot.
17.	Laminated gray sandy clay	6 feet.
18.	Indurated laminated yellow clay	½ foot.
19.	Laminated gray sandy clay	2 feet.
20.	Thin stratum of limestone	½ inch.
21.	Laminated gray sandy clay with partings of ferruginous matter	20 feet.
22.	Ferruginous clay	20 feet.
23.	Laminated gray sandy clay with partings of ferruginous matter. On the upper side of this deposit there is a joint south 40 degrees east	44 feet.
24.	Yellow laminated clay	1 foot.
25.	Dark gray sand	7½ feet.
26.	Grayish yellow sandy clay containing small calcareous concretions	15 feet.
27.	Indurated sand with nodules	⅓ foot.
28.	Grayish yellow sandy clay with calcareous concretions	21 feet.
29.	Covered up to creek	30 feet.

Going northwest from this section the first exposure seen is in a small stream near the village of Grand Saline. The section in this cut is:

1.	Brown sand	3 feet.
2.	Bluish gray sand	2 feet.
3.	Laminated sandy clay	8 feet.
4.	Ferruginous sandstone	1 foot.
5.	Laminated brown sand	1 to 5 feet.

These beds dip north 80 degrees west at an angle of 9 to 14 degrees. Half a mile further to the northwest, and near the crest of the hill, the brown ferruginous gravel and nodules of iron ore and ferruginous sandstone overlie stratified gray sand dipping north 60 degrees west.

A section at this place gives the following:

1. Yellowish brown sand containing nodules of iron ore and broken sandstone . . . . 40 feet.
2. Ferruginous gravel with iron nodules . . . . 4 feet.
3. Gray stratified sands showing such irregular dips as to give the beds the appearance of being cross-bedded . . . . 6 feet.

From this place the level of the country descends toward Caney creek, and the section shows a series of laminated fossiliferous sands and clays with occasional thin seams of lignite. A section on the northwest quarter of the Peter Benton headright shows:

1. Yellow sand, stained brown in spots, containing broken ferruginous sandstones and fragments of silicified wood . . . . 8 inches.
2. Gray sand . . . . 2 feet.
3. Mottled blue and red sandy clay . . . . $1\frac{1}{2}$ feet.
4. Laminated blue clay . . . . 6 feet.
5. Lignite . . . . 4 inches.
6. Mottled sandy clay . . . . 2 feet.
7. Stratified sand with thin seams of clay containing fragments of plants . . . . 4 feet.

Three hundred feet further down the creek (north), the lignite, No. 5, shows an outcropping eighteen inches thick.

Sufficient information has not yet been obtained to definitely locate the south side of the saline, or the position of the fold. The few sections obtained during the course of the work show variable dips from the south to the northwest.

On the south side of the saline basin, and between it and Saline creek, there exists a ridge of gravelly sand with occasional deposits of a yellowish white sandy clay, rising about forty feet above the level of the plain and extending in a nearly easterly course (south 70 degrees east).

The section near the base of this ridge shows:

1. Brown ferruginous sand . . . . 2 feet.
2. Yellowish white sandy clay, dipping south . . . . 5 feet.

Another cut further east, along the same ridge, shows a section of a gray clayey sand, bluish tinted at the base and yellow toward the top. Where the section was obtained the bed appeared to fold over, having a dip of south 20 degrees east 1 degree on the eastern end, and north 38 degrees west 2 degrees at the western end.

These were the only sections seen along this side of the saline proper.

Saline creek and its flood plain form the chief boundary of the southeast portion of the saline. No sections of any kind have been obtained from any portion of this side of the saline south of the line of railway.

North of the road the sections obtained from several cuts shwo a

series of beds differing in some respects from those to the west and dipping towards the east and southeast.

On the northeast corner of the Samuel Bell headright, about two miles northeast of Grand Saline, a cut in an old road shows a section of:

1. Brown ferruginous sand . . . . 6 feet.
2. Gray laminated clays dipping north 30 degrees west . . . . 20 feet.

On the east side of the same headright, and within half a mile north of the railway, a section shows:

1. Surface gray sandy soil . . . . 1 foot.
2. Brown unstratified sand . . . . 5 feet.
3. Brown stratified sand . . . . 3 feet.
4. Thin seams of lignite . . . . ½ inch.
5. Stratified bluish sandy clay, containing impressions of fossil plants, notably the *Sabal* . . . . 3 feet.

Near the north side of the cut the stratified sandy clay, No. 5, is broken and jointed. The joints are nearly perpendicular and have a south 20 degrees west course.

Three miles east of Grand Saline station a small hill rising from the bottom land shows a deposit of stratified sand dipping south 60 degrees, east 8 degrees. This is the first section obtained on the east side of the saline basin, and in all probability is at least two miles beyond the region controlled by the structure of the saline.

The structure of the beds of yellow sandy clay containing limy concretions found lying near the base of the section north of the saline, and dipping north 10 degrees west 7 degrees, appears to be the same as the yellow stratified sands and clay with the same character of concretions found at Wills Point, dipping southeast 2 degrees, south 2 to 5 degrees. If so, then it would appear that these beds form a syncline or trough between these two points, a distance of nearly twenty-five miles, and from the observed dip along the line of the section the deepest portion of this trough would be a short distance east of the present course of Caney creek, and correspond closely to the synclinal axis now seen in the upper beds.

The bearing of the Cretaceous limestone forming the base of Grand Saline and overlying the salt deposits of that region is not so well understood as yet. But from what is at present known these beds appear to have exercised some influence in causing the folding of the overlying clays and marls. In addition to the western fold of the bed, the black or blue clay found in the borings of Grand Saline also occur in a boring at Mineola, fourteen miles further east, at a depth of one hundred and eighty feet. From this it would appear that these beds, after passing the Grand Saline fold, resume their normal dip toward the southeast.

FROM GRAND SALINE EAST TO MINEOLA.

Going east, the first section of any importance occurs four miles from Grand Saline, where a cut gives the following section:

1.	Soil	6 inches.
2.	Brown sand	4 feet.
3.	Gravel and sand	6 inches.
4.	Yellowish gray sand	4½ feet.
5.	Dark colored clayey sand	1 foot.
6.	Gray sand	2½ feet.
7.	Brown sand	2 feet.

The only other cuts seen between this and Silver Lake station show brown sand. A little west of the station a deep ravine and railway cut show a combined section of:

1.	Mottled sandy clay	5 feet.
2.	Laminated sand and clay	4 feet.
3.	Laminated ferruginous matter and sand	10 feet.
4.	Thin stratum of laminated iron ore	6 inches.
5.	Grayish yellow sand	1 to 2 feet.
6.	Nodules or concretions of iron ore	2 feet.
7.	Gray sand, black near center of cut and contains numerous crystals of gypsum	4 feet.
8.	Covered up, probably same as No. 7	15 feet.
9.	Purplish blue clay	1½ feet.
10.	Blue laminated sand in creek	4 feet.

These beds dip southeast at an angle of 3 degrees.

From Silver Lake the country falls toward Sabine river, and is covered with a gray sand overlaid with a brown sand. Sands form the only deposits seen until within two miles of Mineola, where a section gives:

1.	Brown sand	4½ feet.
2.	Mottled sandy clays	4 feet.
3.	Laminated clay	1½ feet.

The clay is not continuous, as in a section not more than fifty feet further east it is replaced by a laminated gray sand. A section here gives:

1.	Surface soil	10 inches.
2.	Mottled sandy clay weathering yellow	4 feet.
3.	Blue laminated shaly clay, with partings of light brown sand	10 feet.
4.	Mottled unstratified sand	4 feet.
5.	Laminated gray sand	15 feet.

A well bored at Mineola gives the following section:

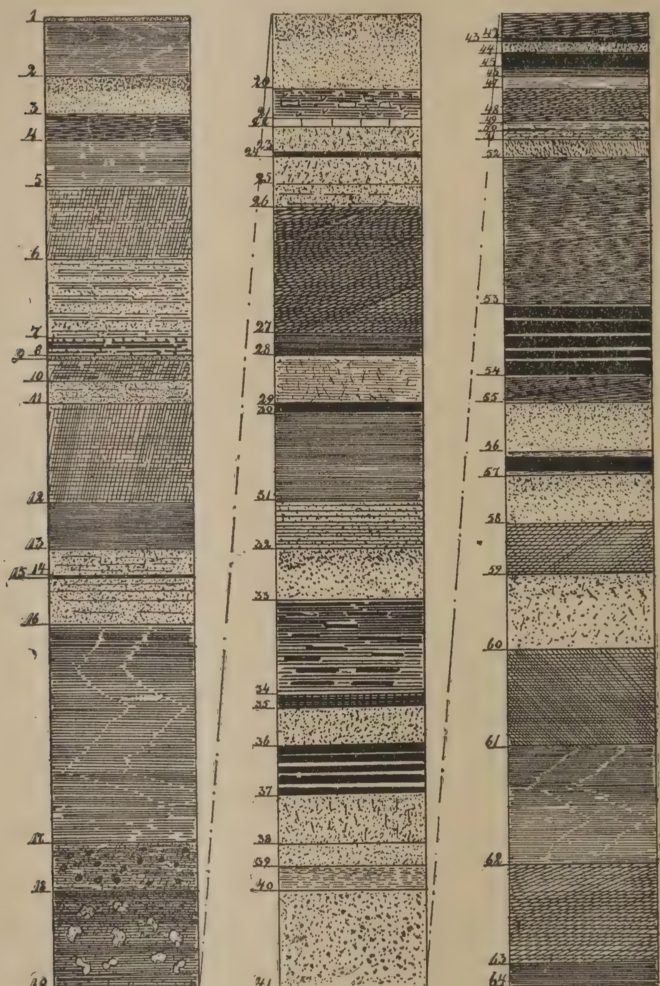

Fig. 4.
Well at Mineola. Scale 1 inch=40 feet.

SECTION OF WELL AT MINEOLA.

		Thickness.	Depth.
1.	Top soil	1 foot.	1 foot.
2.	Red clay	11 feet.	12 feet.
3.	Gray or white sand with water	8 feet.	20 feet.
4.	Brownish black clay	5 feet.	25 feet.
5.	Brown clay	10 feet.	35 feet.
6.	Blue clay	15 feet.	50 feet.
7.	Brown clay, sand and mica	16 feet.	66 feet.
8.	Lignite sand and iron pyrites	4 feet.	70 feet.

9.	Sandstone with water	1 foot.	71 feet.
10.	Blue clay or mud	4 feet.	75 feet.
11.	Gray sandstone with water	5 feet.	80 feet.
12.	Blue clay	20 feet.	100 feet.
13.	Potter's clay	10 feet.	110 feet.
14.	Sandstone with water	5 feet.	115 feet.
15.	Gray or blue clay	½ foot.	115½ feet.
16.	Sandstone with water	9½ feet.	125 feet.
17.	Bluish gray clay and pyrites	45 feet.	170 feet.
18.	Bluish gray clay with some sand	10 feet.	180 feet.
19.	Blue clay with limestone bowlders	20 feet.	200 feet.
20.	Gray sand	15 feet.	215 feet.
21.	Black clay with limestone, pyrites, etc.	6 feet.	221 feet.
22.	Dark limestone	2 feet.	223 feet.
23.	Gray sand and mica	5 feet.	228 feet.
24.	Black and blue clay, mica and pyrites	1 foot.	229 feet.
25.	Gray sand, mica, brown clay and water	6 feet.	235 feet.
26.	Sandstone with water	4 feet.	239 feet.
27.	Brown black clay	26 feet.	265 feet.
28.	White clay	5 feet.	270 feet.
29.	White or gray clay, sand, mica and pyrites with water	10 feet.	280 feet.
30.	Lignite	1 foot.	281 feet.
31.	White clay with thin strata of sand with water	19 feet.	300 feet.
32.	Brown clay and white sand	10 feet.	310 feet.
33.	White sand with water	10 feet.	320 feet.
34.	Brown clay and lignite	20 feet.	340 feet.
35.	Brown joint clay	2 feet.	342 feet.
36.	Gray sand	8 feet.	350 feet.
37.	Gray sand and lignite	10 feet.	360 feet.
38.	Gray sand and pyrites	10 feet.	370 feet.
39.	White sand	5 feet.	375 feet.
40.	Grayish white sand and black mud	5 feet.	380 feet.
41.	Coarse white sand with grains of lignite and water	20 feet.	400 feet.
42.	Brown clay	5 feet.	405 feet.
43.	Lignite	1 foot.	406 feet.
44.	White sand, very coarse, with water	2 feet.	408 feet.
45.	Lignite	3 feet.	411 feet.
46.	Gray clay	2 feet.	413 feet.
47.	Grayish white clay	3 feet.	416 feet.
48.	Brown clay	5 feet.	421 feet.
49.	Dark brown clay	1 foot.	422 feet.
50.	Black mud	2 feet.	424 feet.
51.	Black mud, sand and lignite	2 feet.	426 feet.
52.	Iron pyrites and black mud	4 feet.	430 feet.
53.	Black brown clay and pyrites	30 feet.	460 feet.
54.	Lignite	15 feet.	475 feet.
55.	Black brown clay	5 feet.	480 feet.
56.	Gray sand with water	10 feet.	490 feet.
57.	Lignite	5 feet.	495 feet.
58.	White sand with water	10 feet.	505 feet.
59.	Dark brown joint clay	10 feet.	515 feet.
60.	Gray sand mica and water	15 feet.	530 feet.

61.	Dark brown clay	20 feet.	550 feet.
62.	Grayish blue clay	25 feet.	575 feet.
63.	Dark brown clay	20 feet.	595 feet.
64.	Joint clay and sand at bottom of boring	5 feet.	600 feet.

2. SECTION FROM MINEOLA TO TYLER ALONG THE LINE OF THE INTERNATIONAL AND GREAT NORTHERN RAILWAY.

This section extends in a southerly direction from Mineola to Tyler, a distance of twenty-five miles. The line passes principally through a low country, descending, for the first four miles, from Mineola towards the Sabine river, and after crossing a wide flood plain or bottom land, rising by successive stages until it reaches Tyler, where it has an elevation of one hundred and ten feet above Mineola, or five hundred and thirty-one feet above tide water.

The actual termination of this line at its northern end is about a mile east of Mineola station, where a railway cut and stream channel show the following sections:

Section shown in cut on Texas and Pacific Railway about one mile east of Mineola:

1.	Gray surface soil	10 inches.
2.	Yellow mottled sandy clay	1½ feet.
3.	Mottled yellow and red sand	4 feet.
4.	Stratified sand	2 feet.

In the stream channel from fourteen hundred to sixteen hundred feet east of last section, the section is as follows:

1.	Gray sand stained brown in places	2 to 4 feet.
2.	Gravel and siliceous pebbles	2 to 10 inches.
3.	Cross-bedded brown sand	4 feet.
4.	Alternating strata of gray sand and purple colored clay. The clay having changing thicknesses from ten inches at the base to less than half inch at the top, and the sandy strata from one foot at the base to four feet at the surface	20 feet.
5.	Stratified blue and gray sand, same as seen in railway cut	2 feet.

No. 4 of this section dips at the high angle of thirteen degrees at its western end, but gradually assumes the normal dip of three degrees on going eastward, and No. 5 bends down under the overlying beds at their western end. The high dip of No. 4 may be ascribed to and is probably due to the erosion of some of the underlying deposits.

Going southward along the line of section the country is covered by a brown sand two to five feet thick, resting upon a gray sand four feet thick.

A short distance south of this the combined section of several small cuts shows:

1.	Brown sand	2 to 5 feet.
2.	Thinly stratified or laminated sand and ferruginous material	6 inches to 4 feet.

3.	White or grayish white sand	3 to 5 feet.
4.	Dark blue clay	10 to 12 feet.

These beds dip 2 degrees south 40 east.

The surface of the blue clay presents an undulating appearance, as if it had been subject to erosion before being overlaid by the gray sands. Wherever this clay is seen in a cut it has a mound shaped appearance, showing heaviest in the center of the cut, and rarely extending so as to be seen at both ends.

Crossing the Sabine river bottom lands, which are here nearly two miles in width, the southern bank of the river shows a section of:

1.	Brown sand	10 feet.
2.	Laminated dark blue clay	60 feet.
3.	Lignite	2 feet.

Near mile post 37, about a mile south of the last section, a small cut shows a basin-shaped series of beds giving the following section:

1.	Surface soil (black)	2 feet.
2.	Gray sand	2 to 5 feet.
3.	Lignitic material	10 inches.
4.	Brown clay containing broken plant remains	2 feet.
5.	Gray sand, visible	2 feet.

Nearly three hundred feet south of this section the lignitic material crops out at the base of the section, dipping slightly in a southeasterly direction.

Throughout the next three miles the section presents a series of undulations, showing comparatively low dips on their northwestward sides, and short steep dips towards the southeast.

A cut near the base of the hill, on which is situated the railway tank, and near mile post 36, shows a section of:

1.	Dark soil	10 inches.
2.	Yellowish brown sand	2 feet.
3.	Gray sand	1½ feet.
4.	Cross-bedded brown sand	3 feet.
5.	Laminated blue sand and brown clay with lignitic partings	6 feet.

The dip of these beds is very small and towards the west.

The cut shown in the hill just north of the tank gives the section of:

1.	Surface, grayish white sand	1 foot.
2.	Mottled sand	4 feet.
3.	Laminated sand	4 feet.
4.	Massive pink sand	6 feet.
5.	Laminated dark gray sand	3 feet.
6.	Laminated gray sand	4 feet.
7.	Laminated dark lignitic sandy clay with yellow efflorescence	2 feet.
8.	Shaly lignite	8 inches.
9.	Lignitic material, sand and broken plants	8 inches.
10.	Dark, almost black, lignitic clay	4 feet.

The dip of these beds is variable. All the beds under the lignite, No. 8, dip south twenty degrees east about three degrees, and the overlying beds in the same direction with a less than two degree inclination.

The next cut, eighteen hundred feet south of mile post 35, shows a change both in material and direction of dip, the upper division of this section being a heavy deposit of unstratified white sand, and the lower a mottled brown sand with white spots, dipping north 10 degrees west 3 degrees. The white sand of this section extends to near the crest of the cut north of the tank and rises to a considerable height above the line of rails.

Fifteen hundred feet north of mile post 34 the cut shows the first indication of ferruginous sandstone and gravel, in the shape of a one inch seam lying between the yellow and mottled brown sand. Southward, a few hundred yards, the first ferruginous gravel and broken sandstone seen on this division of the line occur. These gravels are made up chiefly of brown sand, ferruginous sandstones, small nodules or pieces of iron and brown sand. From near mile post 34 these gravels are overlaid by whitish yellow sand as far south as Lindale, where the region round about is covered by it. At mile post 32 it is replaced by a brown gravelly sand. Four hundred feet further south a shallow cut shows:

1.	Brown sand containing scattered siliceous pebbles and gravel . .	2 feet.
2.	Mottled sandy clay, irregularly deposited and containing occasional gray sandstone bowlders	1 to 5 feet.

A short distance further south a creek cut shows the mottled sandy clay to be underlaid by a dark blue clay. These deposits have a slight dip southeast, but so small as to be scarcely appreciable in the short distance they are exposed. Three thousand feet south of mile post 32 a cut shows a section of:

1.	Light gray sand	3 feet.
2.	Cross-bedded sand, containing nodules or small bowlders of sandstone at north end, the nodules lying in a stratum or line dipping 17 degrees and the sand 9 degrees south 50 degrees east . .	4 feet
3.	Light blue clay	. . . .

Eight hundred feet north of mile post 31 the road passes through a cut showing white sand, mottled on the outside and irregularly deposited, but with a general tendency of dip 6 degrees south 25 degrees east.

This section is the beginning of a series of wave-like undulations showing the deposits dipping alternately toward the northwest and southeast. The beds chiefly involved are variously colored sands and light and dark blue laminated clays. In nearly every instance in which an anticlinal arch or fold has occurred it is cut and deeply eroded, and in many places they now form the channels of existing streams.

One thousand feet south of mile post 31 a section in a cut shows:

1. Gray sand . . . . 3 feet.
2. Thinly stratified blue sand and clay dipping north 35 degrees west 6 degrees . . . . 5 feet.
3. Blue laminated clay to bottom of stream . . . . 15 feet.

Two thousand feet south of this the thinly stratified blue sands and clays are the only deposits visible above the line of the railway, and dip south 15 degrees west 3 degrees. Between these two sections the upper part of the anticline has been removed by denudation.

From this point to mile post 31 the country is covered with a brownish gray sand, showing an occasional depth of five or more feet, with an underlying deposit of mottled sand showing here and there at irregular distances. At mile post 30 a gully shows a section of:

1. Surface brown sand . . . . 1 foot.
2. Brown mottled sandy clay . . . . 1 to 4 feet.
3. White clayey sand . . . . 2 to 5 feet.

These deposits dip 3 degrees south 35 degrees east.

Two thousand feet further south a heavy cut in the road shows a section of:

1. Yellow sand at north end of cut . . . . 2 feet.
2. Blue sand . . . . 1 to $2\frac{1}{2}$ feet.
3. Gray sand spotted brown in places . . . . 1 to 4 feet.

The dip of the sand shows north 30 degrees west 1 degree, while the underlying gray sand reverses the dip to south 15 degrees east 1 degree. The gray sand does not extend more than half way through the cut.

Ascending the hill to mile post 29, six hundred feet north of this point, the hill shows a section of:

1. Brown sand . . . . 1 to $1\frac{1}{2}$ feet.
2. Thin seam of ferruginous sandstone and laminated iron ore . . 4 inches.
3. Brown sand . . . . 2 feet.
4. Mottled blue and red sandy clay . . . . 2 feet.

The dip of these beds is very small, but towards the southeast. At the mile post the same cut shows a section of:

1. Gray surface sand . . . . 1 foot.
2. Stratified mottled sand, equivalent to the mottled sand of last section . . . . 4 feet.
3. Thin seam of ferruginous sandstone thickening toward the south . . . . 1 to 6 inches.
4. Stratified bluish gray sand . . . . 4 feet.

The dip of these deposits is north 30 degrees west 2 degrees.

At the south end of the cut the brown sand again covers the surface, and continues as far south as mile post 28, where it appears overlying a mottled sand. At different places small deposits of ferruginous gravel appear associated with the brown sand.

Eight hundred feet south of mile post 28, the same laminated and mottled sands appear, overlying a blue sandy clay, and dipping north 30 degrees west 2 degrees, in the following section:

1. A light gray laminated and cross-bedded sand, slightly basin-shaped at north end, but having a prevailing dip of north 30 degrees west 2 degrees	1 to 8 feet.
2. Laminated grayish blue sand running under No. 1, 500 feet south of north end of cut, dipping north 30 degrees west 8 degrees	4 feet.
3. Unstratified brown sand	1 to 5 feet.
4. Mottled stratified sand	10 feet.
5. Stratified white sand	10 feet.
6. Blue sandy clay in bottom of creek	4 feet.

From this place to mile post 27 the few small cuts show similar sections. Six hundred feet north of the mile post a section shows:

1. Gray sand	2 feet.
2. Brown and mottled sand	4 feet.
3. Stratified blue clay	6 feet.

For the next three miles, to mile post 24, the line passes through a region of gently undulating gray and yellow, with occasional exposures of red or brown sands.

Four hundred feet north of mile post 24 the section shown in a small cut is:

1. Gray sand	1 foot.
2. Yellow sand	4 feet.
3. Mottled sandy clay	3 feet.

The gray and yellow sand of this section continues for nearly two thousand feet, when a section shows:

1. Mottled sand with ferruginous sandstone	2 to 4 feet.
2. Pale blue clay	1½ feet.
3. Brown sand	4 feet.

These deposits are covered a few yards further south by a heavy deposit of white sand.

Fifteen hundred feet north of mile post 23 the white sand is underlaid by a laminated blue clayey sand dipping north 28 degrees west 2 to 12 degrees, but only four hundred feet distant the section shows the dip to be north 28 degrees west 15 degrees. Six hundred feet south of the mile post, on the south side of the stream, the section shown in the cut gives the same laminated blue sands overlaid by a pale blue clay four feet thick dipping south 25 degrees east 5 degrees. Here again the crest of the anticline is broken by two stream beds and eroded to a considerable depth.

Fifteen hundred feet north of mile post 22 the same clay is seen in a section, and one thousand feet south the clay is overlaid by a small seam of lignite, as shown in the following section:

1. Gray sand . . . . 8 feet.
2. Brown sand . . . . 3 feet.
3. Lignite, dipping south 40 degrees east . . . . 6 in. to 1 foot.
4. Blue clay in north end of section . . . .

Four hundred feet north of mile post 21 a cut shows a section of:

1. Brown sand . . . . 1 to 3 feet.
2. Pale blue clay, weathering almost white and containing a thin streak of pure white clay . . . . 4 feet.
3. Light yellowish sand or clayey sand . . . . 1 to 4 feet.
4. Mottled stratified sand . . . .

These beds dip south 28 degrees east 8 degrees.

Between this point and Tyler no satisfactory exposures could be obtained. The hillsides are covered by a broken and disturbed series of sands and sandy clays, and in the few ravines or stream cuts, where undisturbed material is to be seen, the deposits appear to be the thinly stratified red and white, rarely blue, sands and clays found throughout the counties further east and northeast, attaining their best development in Cass and Marion counties.

The few sections found in the neighborhood of Tyler show a prevalence of these last mentioned sands and clays, in some places overlaid by brown ferruginous sands and gravel, at others having a mottled clay or sandy clay in close contact, and at others again covered by thinly stratified brown or yellowish brown indurated sands with small streaks of ferruginous material interstratified. Like the main deposits of these stratified red and white sands, as seen elsewhere, they rest upon a brown or yellowish brown sand, which in turn overlies a gray sandy clay.

Two miles north of Tyler, on the Tyler and Mineola public road, there is an exposure of twenty feet of thinly stratified gray sandy clay, or clayey sand, dipping south 32 degrees east 5 degrees. Southward, along the same road, on the southeast corner of the M. Fenton headright, a cut on the road shows a section of:

1. Surface soil . . . . 1 foot.
2. Ferruginous gravel . . . . 1½ feet.
3. Yellow stratified sand . . . . 4 feet.
4. Mottled sandy clay . . . . 5 feet.
5. Yellow sand with streaks of white clay . . . . 15 feet.
6. Pinkish mottled sand . . . . 8 feet.
7. Stratified clay . . . . 12 feet.

These beds dip south 28 degrees east 2 degrees.

A well in this neighborhood, fifty-six feet deep, finished in a black dirt, probably lignite.

Close to Tyler, on the same road, a small cut shows the red and white sands lying nearly horizontal.

About a mile northwest of Tyler, on the Canton and Tyler road, a small section shows:

1.	Brown sand	2 feet.
2.	Mottled white and red sand containing gravel	2 to 8 feet.
3.	Blue joint clay, visible	4 feet.

Immediately west of Tyler the lowest deposits to be seen consist of thinly laminated red and white sand and clay overlaid by a yellow sand.

Within the limits of the town of Tyler the same characteristic sands and clays crop out at various places where the streets have been graded. At the corner of Beckham and East Erwin streets the section shown is:

1.	Brown ferruginous sand and gravel	2 feet.
2.	Thinly stratified red and white sand and clay	8 feet.
3	Brown or yellowish brown sand seen at west end of grade	3 feet.

On South Broadway, immediately below the opera house, the same stratified sand and clay lie upon a stratified brown sand, and are overlaid by stratified ferruginous sand and gravel. Going east from Tyler, on the Longview road, a cut close to the eastern limit of the corporation gives a section of:

1.	Gray sand	1foot.
2.	Mottled gray and brownish yellow sand	15 feet.
3.	Irregular deposits of ferruginous gravel lying on eastern slope of hill	1 to 6 feet.
4.	Ferruginous sandstone	6 inches.
5.	Laminated brown sand, with laminæ of pale gray clay, the sand averaging one to four inches and the clay one-fourth to one inch in thickness	23 feet.

Six hundred yards east, on the same road, the stratified sands and clays appear underlying the mottled sand. In this section the clay is predominant.

These red and white sands can also be seen at intervals along the the line of the International and Great Northern Railroad as far south as two miles north of Troupe.

3. SECTION FROM TYLER SOUTHWARD, ALONG THE LINE OF THE TYLER SOUTHEASTERN RAILWAY TO LUFKIN.

The general course of this section is from south to southeast through a portion of Smith, the whole of Cherokee, and a portion of the northern end of Angelina counties.

In the neighborhood of Tyler the red and white stratified sands appear dipping in two directions—those on the east of the town in an east and southeast direction, while those exposed on the west have a general northwest to west course. The tops of the hills are covered with a stratified brown sand containing thin seams of ferruginous matter.

Passing southward along the line of section, the country is covered with a light gray sand, under which is found a brown sand with occasional outcroppings of the stratified red and white sands for a distance of about nine miles, after which nothing but a brown ferruginous and gravelly sand appears.

The sections obtained along this portion of the line are comparatively unimportant, and with very few exceptions show nothing but a series of gray, brown, yellow and mottled sand, with occasionally a pale blue clay.

A section near the station at Tyler shows:

1. Gray sand . . . . 1 foot.
2. Pinkish brown sand . . . . 2 feet.
3. Coarsely stratified red sand, in strata from one to two inches, with interlaminæ of white clay from one-fourth to one-half inch in thickness . . . . 4 feet.
4. Brown cross-bedded sands, containing shells of ferruginous sandstone and iron ore . . . . 5 feet.

The dip of these beds is north 10 degrees west 3 degrees.

Half a mile further south a small cut shows a section of:

1. Brown sand . . . . 4 feet.
2. Coarsely stratified sand . . . . 3 to 4 feet.

Two miles south of Tyler, a section shown in a gully gives:

1. Soil . . . . 1 foot.
2. Brown sand . . . . 2 to 6 feet.
3. Mottled sand . . . . 2 to 8 feet.

In this cut the mottled sand dips slightly toward the northwest.

A short distance further south a hill shows a section of:

1. Yellowish brown sand . . . . 5 feet.
2. Stratified sand and sandy clay in thin strata or laminæ . . . . 5 feet.

The dips seen in this section are irregular, dipping from one to twenty degrees in the lower division, and although mostly north 28 degrees east, the stratified sands and clays are frequently folded so as to present southerly directions.

Four and a quarter miles south of Tyler a section shows:

1. Gray sand . . . . 1 foot.
2. Mottled sand . . . . 2 feet.
3. Ferruginous gravel . . . . 6 inches.
4. Pale blue clay, stained red in places, dipping north at a small angle . . . . 1 to 4 feet.

Gray sand forms the surface and covers everything as far south as mile post 9, where the few sections obtained may be combined as follows:

1. Gray sand . . . . 3 feet.
2. Brown sand . . . . 5 feet.
3. Mottled sandy clay . . . . 6 feet.

Three hundred feet north of mile post 10 the next section shows six feet of mottled sandy clay overlaid by a yellow sand.

Eighteen hundred feet south, the section shown in a creek gives:

1. Gray sand . . . . 3 feet.
2. Mottled stratified sand . . . . 4 feet.
3. Spotted blue and red sandy clay . . . . 3 feet.

These beds dip south 30 degrees east 5 degrees.

Four hundred and fifty feet further south a deposit of pale blue sandy clay is intercalated, giving a section of:

1. Gray sand . . . . 3 feet.
2. Yellow sand . . . . 3 feet.
3. Pale blue sandy clay . . . . 3 feet.
4. Stratified mottled sand . . . . 4 feet.
5. Spotted sandy clay, changing to gray sandy clay, at base . . . . 3 feet.

From this point southward, to near Bullard, the country is covered by two feet of gray sand which is underlaid by a mottled sand of five or more feet in thickness.

Near Bullard the first greensand beds appear. These probably form the base of the glauconitic division of the Tertiary deposits in this portion of the State, which extend as far south as Alto, in Cherokee county, and Crockett and Alabama bluff, in Houston county, to which, with their accompanying iron ore deposits, the whole of the flat-topped, plateau-like hills of Eastern Texas owe their structure and preservation.

A well at Bullard, thirty-eight feet deep, gives the following section:

1. Red sand and ferruginous gravel . . . . 7 feet.
2. Greensand, dark greenish gray, with black grains through the first two feet, numerous fossil shells and shark's teeth found near the base . . . . 24 feet.
3. Black earth-like sediment, probably a poor lignite . . . . 2 feet.
4. Lignitic clay, black, and containing small glossy partings of lignite, said to contain a few broken shells . . . . 5 feet.
5. Brown clay, thickness not known . . . .

Going south, the country is underlaid by a yellow colored altered greensand for more than a mile, and then the yellow glauconitic sand disappears under a heavy deposit of brown sand, which, four hundred feet south of mile post 18, is broken by a deposit of white sand six feet thick, and twenty-two hundred feet further south the section shown in a cut is:

1. Gray sand . . . . 1 foot.
2. Yellow and mottled sand . . . . 2 feet.
3. Stratified pale blue and brown mottled clay and sandy clay . . . . . . 2 feet.

These beds dip slightly west of north.

Three hundred feet north of mile post 19 a cut shows a section of thinly laminated iron ores lying over the gray sand and dipping east-

ward apparently, but in a very unreliable fashion. Twelve hundred feet further south a cut shows a section of:

1.	Surface gray sand	6 inches.
2.	Red sand, with a small streak of black iron pebbles near top	1 to 4 feet.
3.	Ferruginous sandstone	6 inches.
4.	Thinly stratified ferruginous matter, seen in north end of cut, and extending south one hundred feet, running under No. 3.	$2\frac{1}{2}$ feet.

These beds dip south 40 degrees east 8 degrees.

Still ascending the hill, a cut from twenty-four to twenty-eight hundred feet south of the mile post, a shallow section shows three bands of irregularly deposited iron ore, interstratified with thin deposits of altered glauconitic brown sand; and twelve hundred feet further south another cut shows a section of:

1.	Brown sand	2 to 3 feet.
2.	Irregularly deposited ferruginous sandstone	2 to 5 inches.
3.	Buff crumbly iron ore	1 to $1\frac{1}{2}$ feet.
4.	Mottled white and red sand	1 to 2 feet.

Four hundred feet south of mile post 20, a well about eight feet deep shows the fossiliferous greensand in the bottom, and five hundred feet further south, the same greensands lie in contact with the surface grayish yellow sands which form the crest of the ridge.

Descending the hill, the first section seen is in a small cut, and next in a ravine about sixteen hundred feet north of mile post 23. The combined section shown gives:

1.	Brown sand, gravel and iron ore	1 foot.
2.	Irregular deposit of laminated iron ore	$1\frac{1}{2}$ feet.
3.	Brown sand	2 feet.
4.	Iron ore	$1\frac{1}{2}$ feet.
5.	Ferruginous sand	3 feet.
6.	Iron ore	1 foot.
7.	Stratified altered greensand	3 feet.
8.	Iron ore	1 foot.
9.	Altered greensand	4 feet.
10.	Iron ore	1 foot.
11.	Altered greensand	2 feet.
12.	Blue clay	2 feet.

A cut, at mile post 23, shows the overlying ferruginous sands and iron ore sand, on top of the last section, eight feet thick, and twelve hundred feet further south a cut, fifteen feet deep, shows a section of:

1.	Ferruginous sand and iron ore	1 foot.
2.	Massive ferruginous sandstone	$1\frac{1}{4}$ feet.
3.	Black sand, with two thin seams of ferruginous matter running through it, the upper seam being three feet from the top of the bed and one inch thick, and the second ten inches lower and slightly thicker than the other. Near the base a thin line of white clayey nodules extend across the bed. (This bed contains very small shark teeth, and a small nodule containing *Cardita planicosta* was also found resting upon the lower ledge of ferruginous material)	8 feet.

4.	Iron ore	1 foot.
5.	Black sand similar to No. 3	$1\frac{1}{2}$ feet.
6.	Ferruginous sandstone	10 inches.
7.	Black sand, visible	1 foot.

The dip of these beds is very slight, and apparently toward the northwest.

The deposit of black sand does not appear at the ends of the cut, but is covered by the brown ferruginous sand (No. 1 of section). Four hundred feet further south a ravine shows the black sand of this section to be underlaid by:

1.	Brown sand	5 feet.
2.	White sand	4 feet.

On the south side of the ravine these sands thicken considerably, and together with the section shown on the hill above them, on the south side of the ravine, gives a section of:

1.	Alternate strata of altered greensand and iron ore, the ore strata not exceeding two inches and the sand one foot	12 feet.
2.	Altered greensand of a brownish green color	6 feet.
3.	Thin stratum of iron ore	6 inches.
4.	Altered greensand	1 foot.
5.	Brown sand	10 feet.
6.	White sand	10 feet.

Going south, another cut, three thousand feet further south of mile post 23, near where the Jacksonville and Mount Selman public road crosses, shows a section of:

1.	Brown sand	2 feet.
2.	Laminated iron ore	10 inches.
3.	Alternate strata of brown sand and iron ore	5 feet.

These beds dip very slightly toward the northwest.

At mile post 24 the altered sands and their accompanying iron ore form the upper division of a section showing:

1.	Brown sand	4 feet.
2.	Alternate strata of brown sand and iron ore, the ore irregularly laid down and not more than six inches thick, the sand approximately two feet	8 feet.
3.	Greensand, dark green in color, and containing numerous casts of small bivalve shells	5 feet.
4.	Black sand, with greenish hue and weathering green	3 feet.
5.	Thin stratum of ferruginous matter	2 inches.
6.	Black sand	1 foot.

The dip of these beds is south 25 degrees east 3 degrees.

At the south end of the cut a small deposit of white clayey sand underlies the greensand No. 3 of section.

From near mile post 24 to mile post 27 the country is covered by a gray sand immediately underlaid by a mottled sand.

A general section of this portion of the line shows:

1.	Gray sand	3 to 5 feet.
2.	Mottled sand	3 to 6 feet.
3.	Brownish yellow sand	4 feet.
4.	Alternate strata of brown sand and iron ore as seen in last section	8 feet.

Thirty-two hundred feet south of mile post 27 a section in a cut shows:

1.	Gray sand	1 foot.
2.	Thinly stratified ferruginous matter	2 feet.
3.	Blue mottled sand	3 feet.
4.	Stratum of laminated iron ore	2 inches.
5.	Greensand, visible	2 inches.

These beds dip very slightly south 20 degrees west.

The section shown in a cut fifteen hundred feet further south shows:

1.	Surface	2 inches.
2.	Brown sand	3 feet.
3.	Altered strata of iron ore and altered glauconitic sands yellow and green in color	10 feet.

These beds dip north 20 degrees west 5 degrees.

At a creek south of mile post 28 the north bank of the creek shows a section of:

1.	Iron ore and brown sand	2 feet.
2.	Yellow colored altered glauconite	1 foot.
3.	Sandstone, yellowish brown in color with dark iron blue spots	1½ feet.
4.	Alternate strata of iron ore and brown sand, ore two to six inches and sand one to two feet in thickness	15 feet.

The creek is one hundred and fifty feet wide, and a quarry on the south side gives a section of:

1.	Dark iron brown sandstone	4½ feet.
2.	Yellowish brown sandstone	2 feet.

The deposits on the north side dip north 20 degrees west 5 degrees, and on the south, south 20 degrees east 3 degrees. At the south end of a cut, close to this quarry, the section shown is:

1.	Yellowish brown sandstone	3 feet.
2.	Heavy bed of sandstone	3 feet.
3.	Brown sand	1½ feet.
4.	Laminated iron ore	10 inches.
5.	Altered greensand with small seams of iron ore	2 feet.
6.	Laminated iron ore	10 inches.
7.	Sand	10 inches.
8.	Iron ore	2 inches.
9.	Altered greenish yellow sand	2 feet.

From near mile post 29 southward, the overlying deposits consist of eighteen inches of brown sand and from four to ten feet of mottled clay, dipping eastward 5 degrees.

South of Jacksonville the country is level and covered with two feet of yellowish colored sand overlying ferruginous sand as far as mile post

31. Seven hundred and fifty feet further south a small cut shows a section of:

1. Ferruginous gravel . . . . 6 inches.
2. Thinly stratified ferruginous sand and altered greensand . . . . . 2 feet.
3. Fossiliferous altered greensand, hardened by exposure and bright red in color, containing only casts of fossils . . . .

Three thousand feet south of mile post 31 the bank of a small creek shows a section of:

1. Red sand . . . . 1 foot.
2. Ferruginous material . . . . 2 feet.
3. Greensand slightly altered . . . . 10 inches.
4. Ferruginous material . . . . 1 foot.
5. Yellowish white sand seen three hundred feet further south . . . .

From this point, to eight hundred feet south of mile post 32, the country is covered with a brown sand containing numerous streaks and pockets of ferruginous gravel, with occasional outcrops of fossiliferous sand. A generalized section gives:

1. Brown sand and ferruginous gravel . . . . 5 feet.
2. Laminated iron ore . . . . 1 foot.
3. Fossiliferous sand (fossils as casts only) and showing in places . . . . 4 feet.

Eighteen hundred feet south of the mile post, a hill on the west side of the road gives the following section:

1. Iron ore in bowlders . . . .
2. Ferruginous gravel and sand, ten feet on the top of the hill, but covering the side down to . . . . 10 feet.
3. Thinly stratified red and white sand, seen under red sand on top of hill at base . . . . 2 feet.

Twelve hundred feet further south the section shown in a cut is:

1. Red sand . . . . $2\frac{1}{12}$ feet.
2. Ferruginous sandstone . . . . $1\frac{1}{2}$ feet.
3. Red sand with white streaks . . . .

Three hundred feet further south, in the same cut, the section shown is:

1. Red sand, with black iron pebbles . . . . $2\frac{1}{2}$ feet.
2. Ferruginous gravel . . . . 2 to 12 in.
3. Brown sand . . . . 1 foot.

At four thousand feet south of mile post the yellow fossiliferous sand is again seen in a cut showing a section of:

1. Red sand . . . . 1 foot.
2. Yellow fossiliferous sand . . . . 3 feet.

A short distance south of this cut a stream channel and cut through a hill shows the following section:

1. Brown sand and ferruginous gravel . . . . 2 to 10 inches.
2. Irregular deposit of gravel . . . . 8 to 15 inches.
3. Altered greensand, weathered brown, dipping 8 degrees south 40 degrees east . . . . 6 feet.
4. Altered greensand, containing white nodules and thin streaks of iron . . . . 4 to 10 feet.

5.	Mottled brown and white thinly stratified sands	2 feet.
6.	Thinly laminated blue sand	6 feet.
7.	Thinly stratified or laminated red and white sand, changing to red sand and white clay near railway, and cracked vertically	6 feet.

The lower beds dip south 40 degrees east 5 degrees.

One thousand feet further south a cut in the road shows at north end a section of:

1.	Brown sand and gravel	1 foot.
2.	Laminated iron ore and sandstone	1 foot.
3.	Altered greensand, wavey and contorted	4 feet.
4.	Laminated iron ore	1 foot.
5.	Greensand	2 feet.

These beds dip south 40 degrees east 5 degrees, and two hundred and fifty feet south are faulted, so that the upper brown sands are thrown down two and a half feet, and thicken to six feet.

One hundred and sixty feet south the mottled red and white sand appears underlying a yellowish sand. A section shows:

1.	Yellow sand	2 feet.
2.	Mottled sand	1 foot.
3.	Stratified white and brown sand	4 feet.

The same character of material extends to eleven hundred feet south of mile post 33, where a deposit of stratified sand and sandy clay occurs in the bottom of a cut. These beds dip south 40 degrees east 3 degrees. At eighteen hundred feet south the mottled sands again appear, and at twenty-two hundred a cut shows a section of ten feet of stratified sand.

Twenty-four hundred feet beyond, a cut six hundred feet long shows six feet of red sand extending one hundred feet into the cut, overlaid by red and white stratified sand and sandy clay, showing the red sand strata about one foot in thickness, and the white sandy clay two inches. These beds dip south 40 degrees east 5 degrees, and are covered at the south end by a deposit of brown sand, and these in turn are covered by a brown sand containing ferruginous pebbles mostly in the form of small pockets.

At thirty-five hundred feet south of the mile post the white and red stratified sands are again seen in the same position as at twenty-four hundred feet, and the section shows:

1.	Brown sand	2 feet.
2.	Stratified white and red sand	4½ feet.

At thirty-six hundred feet the section shown is:

1.	Brown sand	5 feet.
2.	White sand	3 feet.

At mile post 34 the country shows a section of brown sand mixed with a few streaks of white, and containing a pocket of gravel eight feet long and from one to one and a half feet thick. The cut here is two

hundred and fifty feet long and ten feet deep. The gravel deposits are irregularly scattered through the sand. Deposits of the same character continue to thirty-eight hnudred feet south of the mile post, where a section shows:

1.	Brown sand	$1\frac{1}{2}$ to 2 feet.
2.	Layer of ferruginous pebbles	3 inches.
3.	White sand	1 to 10 feet.

The remaining portion of this cut shows a section of:

1.	Brown sand and gravel	2 feet.
2.	Stratified brown sand	4 feet.
3.	Unstratified white sand, with occasional laminæ of ferruginous matter running out at four thousand two hundred and fifty feet	4 feet.
4.	Stratified red and white sands in south end of cut, visible	1 foot.

Twenty-five hundred feet south of mile post 35 the region is covered with white sand overlying a brown sand and stratified sandy clay. A well dug in this region thirty feet deep shows white sand throughout the whole depth.

From fifteen hundred to eight hundred feet north of mile post 35 a cut thirteen hundred feet long shows, at north end, a section of:

1.	Brown sand	1 to 4 feet.
2.	Ferruginous gravel and pebbles, irregularly laid down and occurring in pockets of one foot near south end	6 inches to 1 foot.
3.	Brownish yellow sand, stratified in deposits of ten to eighteen inches, six feet at north end running out at 1140 feet north of mile post	6 feet.

These beds dip south 40 degrees east 5 degrees. The lower bed has a tendency to become more distinctly stratified and higher in color toward the base, and at the south end of cut the gravel becomes thicker and incloses bowlders of sandstone.

Seven hundred and fifty-two feet north of mile post 36 a cut seven feet deep shows a section of:

1.	Gray surface soil	10 inches.
2.	Brown gravelly sand	$1\frac{1}{2}$ feet.
3.	Cross-bedded sand containing small nodules of white clay	$4\frac{1}{2}$ feet.

One hundred and ninety feet south of mile post the section is as follows:

1.	Brown sand and gravel	2 feet.
2.	Gravel	6 inches to 3 feet.
3.	Gray and brown white cross-bedded sand	1 to 3 feet.

Eight hundred feet south of mile post 36 the end of a bed of blue micaceous sandy clay four feet thick is seen in a gully. This bed dips south 40 degrees east 28 degrees, and is overlaid by three feet of red laminated and white sand. A section of a cut near this place shows:

1.	Red sand	1 to 5 feet.
2.	Ferruginous gravel, deposited irregularly in pockets connected by thin seams	6 inches to 2 feet.
3.	Light brown sand	1 to $5\frac{1}{2}$ feet.

At twenty-four hundred and forty feet the brown sand is underlaid by mottled sand. Near Mr. Dial's house, a little to the east of the line of railway, a small hill shows a section of:

1. Ferruginous gravel and red sand . . . . 3 feet.
2. Brown sand . . . . 2 feet.
3. White clayey sand . . . . 2 feet.

The railway line at this place passes through a gap or narrow pass between hills rising over one hundred feet above the line. These hills are capped by ferruginous altered glauconitic limestones and laminated iron ore, and belong to the series of deposits found near Rusk, making up the whole of the elevated plateau-like hills of Cherokee county.

The road passes from Dial southward through a low lying valley covered with brown sandy loam as far as mile post 40. Three hundred and seventy feet north of the mile post there is a cut five hundred and fifty feet in length. The first one hundred feet from the north end of the cut is occupied by a brown sand containing a quantity of ferruginous gravel near and extending along the top of the cut. At one hundred and ninety feet from the north end, a mottled sand commences and extends southerly to the mile post, which is on its upper surface and twenty feet along its base. Between the overlying brownsand and the mottled sand, near the base, there is a pocket of ferruginous gravel six feet long and two feet thick in the center. One hundred and seventy feet north of the mile post the mottled sand is underlaid by a stratified white clayey sand. This deposit slopes upward toward the mile post at about 5 degrees, and then breaks off abruptly on the south side. The upper eighteen inches of this sand is broken and cross-bedded and irregularly stratified. The lower division is more regular in structure. The southern end of the cut is occupied by a brown sand containing pockets of coarse gravel, and between the mottled sand and white clayey sand irregular pockets of gravel occur along the parting. The total depth of the cut, two hundred feet south of mile post, is twelve feet, and the brown and mottled sands dip north 50 degrees west 6 degrees. Twenty-eight hundred feet south the sand seen in a small cut is cross-bedded and contains pockets of gravel. Nothing but a brown ferruginous gravel can be seen from this point to near mile post 42. Twelve hundred feet north of this point a section gives:

1. Gray sand . . . . $1\frac{1}{2}$ feet.
2. Red and yellowish brown sand, with quantities ferruginous gravels and some bowlders . . . . 2 feet.
3. Mottled blue and red sandy clay, stratified and dipping south 70 degrees east 5 degrees . . . . 3 feet.

Four hundred and fifty feet further south No. 3 is underlaid by a pale blue, weathering white, micaceous, thinly stratified sand, a section showing:

1. Gray surface sand . . . . 1½ feet.
2. Yellowish gray and brown sand, with quantities of irregularly deposited ferruginous gravel and a few bowlders of iron ore . . . . . . 2 feet.
3. Mottled blue and red sandy clay . . . . 4 feet.
4. Thinly laminated, pale blue, micaceous sandy clay . . . . 2 feet.

Dipping south 70 degrees east 5 degrees.

Three hundred and seventy-five feet further south No. 3 increases in thickness to five feet.

At mile post 42 a cut shows a section of:

1. Yellow sand, with fragments of ferruginous sandstone . . . . . . 1 to 5 feet.
2. Mottled blue and red laminated sandy clay . . . . 14 feet.
3. Pale blue laminated micaceous sand, to bottom of creek . . . . . 5 feet.

Twenty-five hundred feet further south the cut shows a section of:

1. Gray sandy soil . . . . 1½ feet.
2. Yellow sand, containing black ferruginous pebbles . . . . 3 feet.
3. Laminated red and white sand, in laminæ or thin strata of red from one to two inches and white sand one-quarter to one inch . . . . 1 foot.
4. Laminated brownish yellow sand . . . . 6 inches to 1½ feet.

These beds dip north 40 degrees west 3 to 5 degrees.

From this point to mile post 43 the country is covered with a gray sand, and at 43 the section shown is:

1. Hard orange yellow sand . . . . 1 to 4 feet.
2. Mottled red and blue sand . . . . 4 feet.
3. Blue sand, in creek . . . . 5 feet.

This section continues two thousand feet south, and at twenty-two hundred feet a section shows:

1. Gray sand . . . . 2 feet.
2. Brown or orange or yellow sand . . . . 2 feet.
3. Ferruginous gravel and fragments of a gray sandstone . . . . . . 4 feet.
4. Sand, brown on top, changing to gray near bottom . . . . 4 feet.
5. Brown sand . . . . 1 foot.
6. Grayish blue sand . . . . 1 foot.
7. Purplish gray sandy clay . . . . 1 foot.
8. Gray sand . . . . 10 inches.
9. Purple colored clay, containing a few leaves in a fragmentary condition . . . . 1 inch.
10. Gray sand . . . .

Between twenty-four hundred and twenty-six hundred feet, while the general section remains the same, a deposit of ferruginous gravel, one hundred feet long and from two to ten feet thick, appears beneath the yellow sand, and at twenty-six hundred feet this gravel has thinned out to one foot, showing in the following section:

1. Yellow sand . . . . 6 feet.
2. Ferruginous gravel and sand . . . . 1 foot.
3. Grayish brown sand . . . . 4 feet.
4. Gray sand . . . . 8 inches.
5. Gray sandy clay . . . . 4 inches.
6. Stratified blue sand . . . . 1½ feet.

From this place to six hundred feet north of mile post 44 the surface of the country is covered by a yellowish gray sand. A few small sections are seen, but these correspond with the last section. At eleven hundred feet south of the mile post the section shown is:

1.	Gray sand	1 foot.
2.	Ferruginous gravel	1 to 3 feet.
3.	Brown sand, with small pockets of ferruginous gravel	3½ feet.

From twenty-two to twenty-nine hundred feet south of the mile post a general section shows:

1.	Gray sand	1 foot.
2.	Red sand and ferruginous gravel	5 feet.
3.	Brownish yellow sand with ferruginous gravel	23 feet.
4.	Grayish blue sand	2 feet.

A section of hill near Rusk penitentiary shows:

1.	Gray sand	20 feet.
2.	Interstratified laminated ferruginous material, iron ore and altered greensand, the ferruginous material from one to two inches and the sand from six to ten inches in thickness	40 feet.
3.	Laminated or thinly stratified red and whitish blue sand and sandy clay	20 feet.
4.	Mottled red and blue sandy clay, probably belonging to and forming the lower portion of No. 3	25 feet.
5.	Red sand and ferruginous gravel, lying around base, probably derived from the upper beds	5 feet.
6.	Brownish stratified and fractured sand, mottled in places	60 feet.
7.	Grayish blue stratified sand, in creek at base of hill	3 feet.

The grayish blue sand, No. 7, and the brown mottled sand, No. 6, occur in most of the stream channels and other cuts around the town of Rusk, and No. 7 is also seen in a creek near the Star and Crescent furnace.

West of Rusk, and close to a small creek, a section along the Rusk and Palestine road, beginning close to the Acme Hotel block, and running west, shows:

1.	Brown ferruginous sand, with gravel in pockets	3 feet.
2.	Brown sand, weathered hard and broken into irregular blocks	1½ feet.
3.	Thinly laminated gray sandy clay	2 feet.
4.	Soft yellow sand	6 inches.
5.	Thinly laminated dark purple and almost black micaceous sandy clay, with gray sandy partings	2½ feet.
6.	Thinly laminated brownish gray sand	1 foot.
7.	Dark purple colored clay, similar to No. 5, but containing more mica in partings	1 foot.
8.	Greenish gray laminated sand near top and stratified at bottom. The top laminæ are parted by brown sand	3 feet.

The white sand of this section appears to have pinched out in the last section, and is represented by the yellow sand, No. 4. The white sand occurs about six hundred feet further west, occupying the place of

No. 4, and resting upon the thinly laminated clays, No. 5. The clays representing No. 3 at this point are very thin and irregularly deposited giving them a wavy appearance. A section shows at this place:

1.	Brown sand and gravel	3 feet.
2.	Brown sand	4 feet.
3.	Thinly laminated clay	1 to 6 inches.
4.	White sand	4 feet.
5.	Thinly laminated gray sandy clay	2 feet.
6.	Thin deposit of laminated purple clay	8 inches.
7.	Sand, thinly laminated on upper surface, but without lamination at base	6 inches.

These beds dip south 70 to 80 degrees east 3 degrees.

Near mile post 46 the cut shows twenty feet of white sand, weathering pink on outside, overlying the blue sand seen at bottom of creek channels in neighborhood.

A cut five hundred and twenty feet south of the mile post shows a section of:

1.	Gray sand	3 feet.
2.	Alternate strata of sand and clay—clay one to two inches and sand from four to eight inches	4 feet.

Beds dipping south 40 degrees east 1 degree.

Nine hundred and ten feet further south another section shows:

1.	Gray sand	3 inches to 1 foot.
2.	Brown mottled sand	2 feet.
3.	Pale bluish gray clay with small quantities of sand	4 feet.

No. 3 of this section thickens toward the south, and in Baker's clay pit is over twenty feet thick. Five hundred and sixty feet from west end the south side of the cut shows a section of:

1.	Brown ferruginous sand	4 feet.
2.	Mottled laminated red and white clay and sand, the red sand strata not more than one inch thick	4½ feet.

From west end of cut to this section the dip of the bed is south 40 degrees east 3 to 5 degrees, and at seven hundred and thirty-eight feet east the mottled laminated sands, No. 2 of above section, are broken abruptly and their place occupied by a heavy deposit of brown ferruginous sand with numerous pockets of gravel.

Baker & Co.'s brickyard is situated close to this cut, and a section of the pit shows:

1.	Brown sand and gravel, with small pieces of iron ore	2 to 3 feet.
2.	Alternated strata of potter's clay and gray sand, in thickness of clay six inches to one foot, and in places two feet, sand from six inches to one inch. The clay is purplish gray in color and contains numerous impressions of leaves	8 feet.
3.	Purple colored clay, containing fragments of leaves in a broken and mixed condition, very much resembling drift material	6 in.
4.	White sand, to bottom of pit	2 feet.

These deposits are apparently of a different age than those found in the higher range of hills lying toward the east. A section of a boring on a hill near New Birmingham gives, according to Mr. Mahoney:

1. Clay . . . . 10 feet.
2. Micaceous sandstone, containing iron . . . . 3 feet.
3. Sandstone . . . . 8 in.
4. Micaceous sand . . . . 1 foot.
5. Altered glauconite, containing fossils . . . . 6 feet.
6. Quicksand . . . . 1 foot.
7. Glauconite, altered and containing casts of shells . . . . 10 feet.
8. Sandstone . . . . 1 foot.
9. Altered glauconite . . . . 10 feet.

A section in a railway cut east of New Birmingham station shows:

1. Gray sand . . . . 1 foot.
2. Brown stratified red and white sand . . . . 2 feet.
3. Ferruginous sandstone . . . . 10 in.
4. Stratified brown sand, in strata from one to six inches . . . . 5 feet.
5. Unstratified white sand . . . . 2 feet.

Beds dipping south 40 degrees east 5 degrees. At the west end of the cut at section they are horizontal for one hundred and twenty-five feet, after which they change both in direction and declination of dip. The next section, four hundred and ninety feet from west end, shows:

1. Brown stratified sand, dipping north 40 degrees west 3 to 8 degrees 1 foot.
2. Thinly laminated red and white sands and sandy clays, dipping 8 degrees . . . . 8 feet.
3. Dark blue sand, seen in creek bottom at east end of cut . . . .

Going southward, about three hundred feet, a cut shows a section of stratified material similar to No. 4 of the New Birmingham section, dipping north 40 degrees west 3 degrees, and in a highly contorted condition.

East of the Tassie Belle furnace a cut shows the following sections —from north end to one hundred and fifty feet:

1. Red sand and gravel . . . . 4 feet.
2. Stratified red and white sand . . . . 5 feet.
3. Cross-bedded red and yellow sands . . . . 1 to 3 feet.
4. Stratified blue sand . . . . 5 feet.
5. Brown unstratified sand . . . . 2 feet.

At two hundred and forty-two feet the cross-bedded sand disappears, dipping south 20 degrees east 3 degrees, and the section is:

1. Red sand and gravel . . . . 4 feet.
2. Thin stratum of ferruginous sandstone . . . . 4 inches.
3. Stratified red and white sand . . . . 5 feet.

At three hundred and seventy-one feet south the strata remains the same, with the addition of:

4. Pale pink sand . . . . 2 feet.
5. Stratified red and white sand . . . . 2 feet.

Dipping south 20 degrees east 2 degrees.

At five hundred and ninety-two feet the stratified sand disappears under an irregularly stratified mottled or red sand with occasional strata of white, giving the following section:

1. Red sand . . . . 3 feet.
2. Ferruginous sandstone . . . . 6 inches.
3. Roughly stratified red and white sand, with nodules of iron ore . . 3 feet.
4. Stratified red and white sand . . . . 1 foot.

At seven hundred and twenty feet the overlying red sand forms the section as far as the end of the cut.

Three hundred and eighty-eight feet south of mile post 48, a well eighteen feet deep gives a section of:

1. Pale brown sand . . . . 17 feet.
2. Stratified red and white sand . . . . 1 foot.

This section is seen at mile post where a small exposure of the bed No. 2 is seen in the bank of a creek, and at nine hundred and thirty feet south of the same place, a section shows:

1. Brown sand . . . . 4 feet.
2. Stratified red and white sand . . . . 2 inches.

Dipping south 50 degrees east 5 degrees. These stratified sands also occur at intervals until, at twenty-five hundred feet south of the mile post, the section shown in a stream channel fifteen feet deep gives:

1. Red sand and gravel . . . . 4 feet.
2. Brown sand, No. 1 of last cut . . . . 3 feet.
3. Ferruginous sandstone . . . . 6 inches.
4. Stratified red and white sand . . . . 3 feet.

For the next thousand feet the stratified sand, No. 4 of this section, appears at irregular intervals underlying the brown ferruginous sand and gravel. These sands look as if having a very irregular surface. At four thousand feet they are again seen in the following section:

1. Red sand and gravel . . . . 4 feet.
2. Brown sand . . . . 5 feet.
3. Stratified red and white sand . . . . 4 feet.
4. Brown sand . . . . 4 feet.
5. Stratified sand, same as No. 3 . . . . 3 feet.
6. Brown sand . . . . 1 foot.
7. Stratified clay at base . . . .

Dipping south 40 degrees east 5 degrees.

Eighteen hundred feet south of mile post 49 is a section of:

1. Red sand and gravel . . . . 5 feet.
2. Brown sandstone, consolidated to a soft sandstone . . . . $1\frac{1}{2}$ feet.
3. Stratified sand and clay . . . . 1 to 2 feet.

Dips south 40 degrees east 10 degrees.

Five hundred feet further south another cut shows a reversal of the dip to north 30 degrees west 5 degrees in a section showing:

1. Stratified brown sandstone and gray sandy clay, in strata of one-half to one inch . . . . 4 feet.
2. Gray, almost white, sand . . . . 2 inches to $1\frac{1}{2}$ feet.

In the next section, near Linwood, on the J. D. Jones headright, the dip has again changed to south 40 degrees east 10 degrees. Section is:

1.	Gray sand	1 foot.
2.	Ferruginous sand and gravel	3 feet.
3.	Yellow sand	$2\frac{1}{2}$ feet.
4.	Brown sand	$1\frac{1}{2}$ feet.
5.	Brown sand, with thin laminæ of white clay, sand one-half to one and a half inches and clay one-sixteenth to one-eighteenth inch thick	....

A small pocket of gravel, fifteen feet long and two feet thick, occurs near the center of this cut.

Four hundred and thirty-four feet north of mile post 51 a cut shows a section of:

1.	Gray sand	1 foot.
2.	Fine gravel, irregularly deposited	1 to 2 feet.
3.	Brown sand	1 to 3 feet.
4.	Brown sand, with white streaks	4 to 8 feet.
5.	Blue sand, in bottom of creek	....

At mile post 52 another cut shows a section of:

1.	Ferruginous sandstone and conglomerate iron ore	$1\frac{1}{2}$ feet.
2.	Red sand, with white streaks, same as No. 4 of last section	10 inches.
3.	Gray sand, weathering brown	9 feet.

Thirteen hundred feet further south the section shown in a cut is:

1.	Brown sand	7 feet.
2.	Ferruginous sandstone and laminated iron ore	4 feet.
3.	Stratified red and white sandy clay, containing occasional bowlders of nodular iron ore in red strata	2 feet.

Conglomerate iron ore overlying a brown sand occurs nine hundred and ninety feet north of mile post 53.

On the south side of Berry creek, on the New Birmingham and Alto road, a section shows:

1.	Gray sand	1 to 5 feet.
2.	Yellow sand	5 feet.
3.	Ferruginous sandstone	$1\frac{1}{2}$ feet.
4.	Brown sand	4 feet.
5.	Thinly stratified or laminated clay	6 feet.

One hundred feet south of mile post 55 is a section of:

1.	Gray sand	1 foot.
2.	Red sand and ferruginous gravel	4 feet.
3.	Hard ferruginous sandstone, partially stratified and pitted on weathered surface, yellow colored with some pale blue spots	7 feet.

From a short distance south of Bradshaw to about a mile north of Alto, a distance of nearly thirteen miles, the basal material seen in all deep cuts is a blue sand corresponding to the sand seen in the cut west of Rusk.

ALTO SECTION.

The region around Alto is rolling and covered with a brownish yellow sand. The underlying deposits consist of greensand containing

numerous fossils, which in places form the surface of the higher lands, and where so exposed are usually of a brown color and have the fossils in the form of casts only. Throughout the lower portion of the country south of Alto the exposed greensands retain their green color, or become grayish green, and show the white shells of the fossils either whole or in fragmentary condition. Two miles south of Alto, on the Alto and Homer road, an exposure along the road shows a section of:

1.	Red sand and gravel	3 feet.
2.	Fossiliferous yellow and brown sands, containing casts of fossils only	2 feet.
3.	Brownish gray sand, containing shells in large quantities mostly broken	2 feet.
4.	Dark laminated sandy clay	4 feet.
5.	Dark greensand, containing fossils found in Lewis' well at thirty feet	

Half a mile further south this section is covered by a heavy deposit of gray or white siliceous sandstone.

Seven hundred feet north of Alto station a shallow cut shows the greensand altered to a bright red color and containing casts of fossils only. The section shown is:

1.	Red sand and gravel	2 feet.
2.	Bed of ferruginous matter or altered greensand, containing fossil casts	8 inches.
3.	Fossiliferous greensand	3 feet.

Going west from Alto to Cold Spring church, a cut at the spring shows a section of:

1.	Gray sand	40 feet.
2.	Red sand, containing casts of fossils same as seen in last section	15 feet.
3.	Greensand, containing casts of fossils, in bed of creek	4 feet.

Near the center of the T. Walters headright, four miles west of Alto, a range of flat-topped hills, rising about one hundred feet above the level of the creek, shows a section of:

1.	Gray sand	20 feet.
2.	Indurated yellow sand, containing numerous *Scutellæ*	20 feet.
3.	Covered up to creek	60 feet.

This brownish yellow indurated sand, No. 2, occurs in the neighborhood of McBee's school and on the Waters Berryman farm, five miles northeast of Alto, where it forms bald prairie spots covering an acre or two in extent. The section of one of these places, near Berryman's house, gives:

1.	Soil in patches	6 inches.
2.	Brown altered greensand, containing fossils including *Scutellæ*, etc.	2 feet.
3.	Fossiliferous greensand	40 feet.

North of the school house, on a hill known as Berryman's hill, a section shows:

1.	Thin covering of laminated iron ore, with altered greensand, fossiliferous	10 to 15 feet.
2.	Band of fossiliferous greensand, altered and yellow in color, containing great numbers of shells, chiefly *Ostrea*, *Anomia ephippioides* and *Cardita*. Running through these beds there are numerous seams and nodules of calcite	6 feet.
3.	Covered up to base of hill by debris from fossiliferous beds	60 feet.

At McBee's school house spring a section shows:

1.	Gray sand	20 feet.
2.	Thin deposit of laminated iron ore	1 foot.
3.	Iron pyrites in black sand	2 inches.
4.	Lignite	....
5.	Black clay	4 feet.
6.	Greensand	40 feet.

These beds dip north 50 degrees east 5 degrees.

Going down the branch, a series of sands and clays are found lying unconformable to the greensand deposits forming the hill at the school house, the section at the contact giving:

1.	White sandy clay	1 foot.
2.	Laminated dark blue clay	4 feet.

Half a mile further the section shows:

1.	Red sandy soil	1 foot.
2.	Red sand	6 feet.
3.	Stratified and cross-bedded yellow sand	6 feet.
4.	Black clay	1 inch.
5.	Dark bluish gray sand, with thin streaks of black sandy clay	1½ feet.
6.	Brownish gray sand	1 foot.

On Baptising creek a section shows two deposits of greensand lying forty feet apart. No fossils were found in the upper deposit, but the lower contains great quantities of gasteropods and fish teeth, together with thin streaks or pockets of gravel.

At W. Berryman's house two sections shown in a creek bank give:

1.	Brown sand	36 feet.
2.	Clay ironstone	10 inches.
3.	White clay	4 feet.
4.	Black sand and clay in bottom	....

A quarter of a mile further down the stream the second section shows:

1.	Brown sand	36 feet.
2.	Clay ironstone	10 inches.
3.	Laminated brown sand	4 feet.
4.	Whitish brown clay in bottom	

Throughout the region included between McBee's school house and Cold Spring church, and still further towards the west, the uppermost bed of greensand appears to be a heavy deposit of brown altered glauconitic sand, containing *Anomia*, *Ostrea* and *Cardita*, and calcitic streaks of nodules. This is succeeded by a yellow and brownish gray

indurated sand containing *Scutellæ*, fish teeth and other fossils. The sequence of the beds of this region, so far as yet made out, appears to be:

1.	Gray sand	5 to 20 feet.
2.	Ferruginous sandstone	1 foot.
3.	Iron pyrites and lignite	1½ feet.
4.	Laminated iron ore and brown sand and altered greensand	10 to 15 feet.
5.	Fossiliferous altered brown glauconitic sand, containing *Anomia*, *Ostrea* and *Cardita* and calcite streaks and nodules	6 feet.
6.	Yellowish brown and grayish brown indurated glauconitic sand, containing *Scutella caput-linensis*, fish teeth, *Ostrea sellæformis* and other fossils	20 feet.
7.	Greensands containing casts of fossils	6 feet.
8.	Brown sandstone, altered glauconite with casts of fossils	30 feet.
9.	Greensand, with gasteropods and fish teeth	8 feet.

The beds containing the *Anomia* and *Scutella* form well-marked horizons, and extend across the country from McBee's school house westward to the Trinity river. They are also reported as occuring in the counties of Nacogdoches, San Augustine and Sabine, as well as in Louisiana, still further east.

FROM ALTO SOUTHEAST TO LUFKIN.

Going south from Alto, the character of the deposits changes to beds belonging to an apparently later date, and at mile post 58 the last of the greensand deposits occur.

Nine hundred and ninety feet south of mile post 59 the country is covered with gray and yellow sand underlaid by a mottled sandy clay as far south as mile post 61. The mottled clay has an apparent thickness of at least five feet, and dips south 30 degrees east 2 degrees. In a well at Whitehead the mottled clay is underlaid by a black lignitic clay. Twenty-three hundred feet south of mile post 61 a small cut shows a section of:

1.	Yellow sand	2 to 3 feet.
2.	Mottled sandy clay	4 feet.
3.	Black sandy clay, saline to taste, and showing efflorescence of salt	1½ feet.

Two hundred feet further south is this section:

1.	Brown sand	1 foot.
2.	White sand	2 feet.
3.	Thinly stratified blue sand	4 feet.

No 3 dips north 30 degrees west 10 degrees.

At Coal Camp a cut shows a section of:

1.	Surface gray sand	1 foot.
2.	Yellow sand	1½ feet.
3.	Brown sand	2 feet.
4.	Blue clay	1 to 4 inches.
5.	Stratified yellow sand and white clay, dipping north 40 degrees west	4 feet.
6.	Clay, dipping south 40 degrees east	2 inches.
7.	Brownish yellow sand in north end of cut	1 foot.

Eight hundred and twenty-five feet further south thinly stratified red and white sands appear, overlying No. 2 of this section.

Five hundred feet south of mile post 63 is this section:

1.	Red sand with quantities of ferruginous sandstone	1 to 3 feet.
2.	Stratified light grayish brown sand, with parting of white, the upper portion having the brown strata from two to four inches thick and the white one-sixteenth to one-eighth; the lower division of the bed shows the brown from one-half to one-eighth	5 feet.

No. 2 dips south 35 degrees east 11 degrees.

Twelve hundred feet south of the mile post another section shown gives:

1.	Brown sand	1 foot.
2.	Stratified shaly ferruginous sandstone	1 to 2 feet.
3.	Stratified brown sand	1½ feet.
4.	Stratified blue sands, with brown partings	2 to 4 feet.

These beds dip north 40 degrees west at a very low angle.

From six hundred and sixty feet to one hundred and sixty-five feet north of mile post 64, a brown sandstone is found with occasional pockets of ferruginous pebbles, and near the south end of the cut a rounded deposit of white sand occurs, fifty feet long and five feet thick at center, separated from the overlying brown sand by a layer of gravel.

Near mile post 65 this section is seen:

1.	Brown sand	5 feet.
2.	Light gray clay sand	3 feet.

Three hundred and thirty feet further south the section is:

1.	Stratified brown sand	10 feet.
2.	Thinly laminated blue sand	5 feet.

A short distance south the blue sand gives place to a pink sandy clay six feet thick, which is underlaid by lignitic material; and fifteen hundred feet south of the mile post the section at corner is:

1.	Brown sand	4 to 6 feet.
2.	Thinly stratified gray sand	3 feet.
3.	Stratified or laminated black and dark blue clays	2 feet.

Twenty-three hundred feet south of the mile post the section shown is:

1.	Gray sand	2 feet.
2.	Thinly laminated ferruginous sandstone	6 inches.
3.	Brown stratified sand	2 feet.
4.	Light blue sand	10 inches.

From this place to Forest the country is covered with occasional patches of soft ferruginous sandstone and dark colored sands and sandy clays, having a very slight dip south 80 degrees east, probably averaging less than 1 degree, but in places from 2 to 3 degrees.

At Forest a small seam of brown sandstone showing casts of fossils occurs in a cut for a few yards and is then lost. The country is flat

and sandy for fifteen hundred feet south of mile post 70. On the south side of a creek at this place the section shown is:

1. Red sand and ferruginous gravel . . . . 2 feet.
2. Yellow nodular clay . . . . 1 to 2 feet.
   This deposit is only found within the space of a few yards occupying a place in the underlying
3. Pale blue clay, with a tendency to nodular formation, and having a white efflorescence between the joints . . . . 3 feet.
4. White or bluish white sand, seen in south end of cutting . . . . 2 feet.

Thirty-six hundred feet south of the mile post, No. 3 is again seen six feet thick, the section showing.

1. Coffee-colored brown sand . . . . 2 feet.
2. Pale blue clay, similar to No. 3 of above section. . . . . 6 feet.

At twelve hundred feet north of mile post 71 the same clay is again seen in this section:

1. Brown sandstone and ferruginous sandstone and gravel . . . . 4 feet.
2. Stratified red and white sand and sandy clay, lying horizontally . . . 16 feet.
3. Light colored, almost white, sand . . . . 10 feet.
4. Pale blue clay . . . . 10 feet.
5. White sand . . . .

Seventeen hundred feet south of the mile post a section gives:

1. Brown sand, with ferruginous gravel . . . . 1½ feet.
2. Stratified red and white sands, lying horizontal for three hundred and forty feet at north end of section, and then dipping south 40 degrees east 2 degrees . . . . 4½ feet.

From this point to thirty-four hundred feet south of mile post 75, the country is covered with brown sand containing occasional patches of conglomerate ore and ferruginous pebbles, with the stratified red and white sands occasionally changing to a mottled sand underlying, and showing in several small creek beds. At thirty-six hundred feet south of the mile post a section shows:

1. Gray sand . . . . 1 foot.
2. Brown sand . . . . 1½ feet.
3. Stratified sand . . . . 9 feet.

Near mile post 77 a cut north of the mile post shows a section of:

1. Brown sand . . . . 1 to 6 feet.
2. Stratified blue and white sand . . . . 1 to 8 feet.
3. Yellow and bluish sand . . . . 1½ to 2½ feet.

The upper deposit of brown sand, as well as No. 2, have been cut through in several places and the erosions filled with a yellow mottled sandy clay, as seen in the following figure:

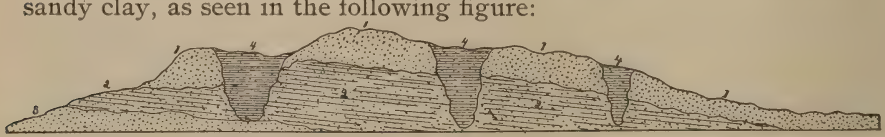

Fig. 5.

1. Brown sand. 2. Stratified blue and white sand. 3. Yellow and bluish sand. 4. Yellow mottled sandy clay.

Six hundred feet south of Bodan a cut five hundred feet long shows a section of:

1. Brown and yellow sand and ferruginous bowlders . . . . 5 feet.
2. Mottled stratified clay . . . . 3 feet.

Four hundred feet south of Baker's switch a section shows:

1. Brown sand and ferruginous sandstone . . . . 1 foot.
2. Mottled red and blue sandy clay . . . . 2 feet.
3. Hard brown and yellowish brown sand, with nodular spots of clay . . 2 feet.
4. Laminated pale blue sandy clay . . . . $1\frac{1}{2}$ feet.
5. Pale blue sand, weathering to a whitish or rusty brown . . . . $1\frac{1}{2}$ feet.

Wells in this neighborhood, dug over twenty feet, show a black sand containing large crystals of gypsum. Five miles south of Bodan a cut, one thousand feet long and about four to eight feet deep, shows a deposit of stratified clay having a tendency to nodular structure. The dip of this and the other beds in the neighborhood is less than 2 degrees south 85 degrees east. This clay is also found exposed in all the cuts along the road to four thousand feet south of mile post 81. It is generally underlaid by a series of stratified blue and red or mottled sandy clay, a general section giving:

1. Mottled and stratified red and blue sandy clay . . . . 4 feet.
2. Laminated pale blue stratified clay, showing a tendency to nodular structure . . . . 8 feet.

The overlying stratified nodular clay continues to be the material shown as far as mile post 82 where it is overlaid by four feet of red sand and a thin layer of ferruginous sandstone. From twenty-five hundred to three thousand feet south of the mile post the deposit exposed is a white clay showing no signs of stratification. A short distance south of mile post 83 we find:

1. Mottled sand containing siliceous pebbles . . . . 2 feet.
2. Stratified light gray sand, dipping north 60 degrees west 5 degrees . . 2 feet.
3. Unstratified gray sand . . . . 6 feet.

Three hundred and eighty feet south No. 2 thickens and cuts off No. 3, and at four hundred feet the same cut shows a section of:

1. Mottled sand . . . . 2 feet.
2. Stratified sand and clay, with a six inch deposit of sand running through the beds. . . . . 6 feet.

At five hundred and eighty feet No. 2 is cut off by No. 1, and at six hundred feet the mottled clay is overlaid by two feet of yellow sand. From here to two thousand feet south of mile post 86 the country is covered by a gray sand, and at the two thousand feet point the section shows:

1. Gray micaceous sand . . . . 9 feet.
2. Stratified ferruginous sand . . . . 1 foot.

The gray sands in this region contain numerous fragments of fossil wood. From this place to Lufkin station the country is covered by a

gray sand, with occasional rounded bosses of brown sand rising to near the surface, sometimes forming the surface soil for short distances. The gray sands weather white, and contain many pieces of fossil wood and limy concretions, as well as siliceous and crystalline pebbles of all sizes. This gray sand shows also a heavy efflorescence of saline material along the banks and bottoms of the numerous dry creeks extending through the area. A section at one place will give the general structure of the whole of the flat area lying northwest of Lufkin through which the line extends:

1.	Pale gray, almost white, sand, containing fragments of gray fossil wood and siliceous pebbles, and showing saline incrustations from one-quarter to one-half inch thick	4 feet.
2.	Thin stratum of ferruginous sandstone	4 inches.
3.	Pale gray sand, same as No. 1	1 foot.

No. 2 is not regular, but is frequently represented by a thin line of pebbles.

The whole of the ninety miles of this section comprises three great formations following each other in the following sequence:

First. The greensand or glauconitic marine formation, containing fossils typical with those belonging to the Claiborne and Jackson formations of Mississippi and Alabama, with which they may be ultimately correlated. This formation extends from Tyler as far south as Alto in Cherokee county, a distance of nearly fifty-seven miles. The area underlaid by these greensand beds is elevated to a considerable extent above the succeeding deposits, and topographically as well as geologically forms the backbone of this portion of east Texas. At Alto, or a few miles south, these beds end somewhat abruptly, and the succeeding deposits follow them unconformably.

Second. A series of sands and clays, beginning a few miles northwest of Rusk and passing down through a long narrow channel as far as Alto, when it turns southwest. The clays belonging to this series are more or less fossilferous, containing impressions of leaves and stems of plants, and in many places associated with lignite.

From Alto southward the same series begins to show itself in the form of sands and thinly stratified sands and sandy clays, the clays becoming heavier but less frequent toward the south, and in the neighborhood of Forest the deep wells show the underlying beds to be chiefly dark gray, almost black, sands, containing large crystals of gypsum. This black sand also occurs near Baker's switch, in wells reaching depths of over twenty feet.

Third. The great formation represented in this section comprises a series of gray sandy clays, containing fragments of silicified wood, and a series of dark blue laminated clay, containing numerous small pockets of gypsum, usually in the form of nests of small crystals. This clay is un-

derlaid by the black sands containing gypsum found in the wells in the neighborhood of Forest and Baker's switch.

Fourth. A formation, consisting of gray and brown sands and sandstones, ferruginous gravels and ferruginous pebbles, conglomerate iron ore and gray sandstones, occurs almost everywhere, either in extensive sheets or in scattered patches, and in thicknesses varying from a few inches to ten or more feet. The gravels of this formation are deposited extremely irregularly, and appear in connection with the brown overlying sands in the form of irregular pockets and thin contorted strata, having no continuous length, and usually not more than a few inches thick, although in places thickening to two or three feet. This formation has no uniform location, but overlies the whole of the other divisions to a greater or less degree, and in places it has been entirely eroded. It may approximately be correlated with the Columbia formation of McGee.

4. SECTION FROM THE ANGELINA RIVER, IN ANGELINA COUNTY, SOUTH TO CORRIGAN STATION, IN POLK COUNTY, ALONG THE LINE OF THE HOUSTON EAST AND WEST TEXAS RAILWAY.

A wide bottom lies along the south side of this portion of the Angelina river, and the section across it discloses nothing but a series of sands and silts common to the flood plains of every river or large stream in this portion of the State. Going south, the first section seen is near mile post 123, where a stream cut on the side of the road gives the section of:

1.	Ferruginous gravel, containing great quantities of siliceous pebbles and fossil wood, the latter being altogether siliceous and gray in color	4 feet.
2.	Stratified blue clay, stained brown in places, and containing interlaminated thin plates and small clusters of minute crystals of gypsum	2 to 4 feet.

A little over one mile south a somewhat similar section is seen on the railway. In this cut the gypseous clays noticed in the last section are four feet thick, and dip south 10 degrees west 5 degrees, and the overlying material is chiefly made up of ferruginous gravel and sand.

From this point southward, through the town of Lufkin, and as far south as Burke, the country is flat and covered with a white sand containing occasional small pockets of siliceous gravel, fossil wood and nodules of calcareous material.

From the records of the few wells dug or bored in this region the area is underlaid by a blue gypseous clay, with occasional streaks or pieces of lignite. The water found in the wells is saline and unfit for use, and the lignite found generally occurs in the form of rounded nodules.

A small prairie in the neighborhood of Burke is covered with the same gray sand showing saline spots throughout the area of the prairie. The beds underlying the prairie are thinly stratified blue clays con-

taining gypsum, and lie within twelve feet of the surface. Going south from Burke, the country continues to fall towards the Neches river, and is covered altogether by a gray sand, with occasional patches of brown, and small spots of siliceous gravel. Occasionally the overlying gray sands become indurated into a soft sandstone and show signs of stratification, dipping south 5 degrees west 3 to 8 degrees. At mile post 110 a section of the bank shows:

1.	Brown sand	6 inches.
2.	Gray sand with white limy streaks	3 feet.
3.	Stratified gray indurated sand or soft sandstone	6 inches.
4.	Blue or brownish blue clay	6 feet.

From mile post 103, southward, to the Neches river, the gray sands are replaced by a coarse yellow sand, extending to the river at Clark's ferry crossing.

On the south side of the river the bottom lands, or flood plains, extend southward to mile post 101, or about a mile and a half south of the river. From this point the country rises rapidly, until at about one thousand feet south of mile post 100 it has attained an elevation of one hundred and twenty feet above the level of the flood plain. This altitude is reached through a series of gray sands, sandstones, gray clays and blue gypseous clays. A combined section of the hill shows:

1.	Gray surface sands, stratified at base, and showing fragments and large blocks of opalized wood. (One of the pieces of opalized wood is in the form of a tree stump standing erect with portions of the main roots attached)	10 feet.
2.	Gray cross-bedded sand	25 feet.
3.	Gray sand with opalized wood	15 feet.
4.	Laminated pink clay	6 feet.
5.	Gray laminated sand	4 in.
6.	Gray sand, stained brown	1 foot.
7.	Thinly stratified gray sand	1 foot.
8.	Gray sandy clay	3 feet.
9.	Gray sandstone	3 feet.
10.	Shaly green clay	1 foot.
11.	Gray and yellow sand	3 feet.
12.	Light yellow or cream colored clay	2 feet.
13.	Thinly laminated gray sandstone	3 feet.
14.	Brown laminated clay	3 feet.
15.	Thinly stratified white and gray sandstones	1 foot.
16.	Gray sandstone stained with iron	3 feet.
17.	Thinly stratified or laminated clay with gypsum, same as seen two miles north of Lufkin at mile post 122 of line	35 feet.

Descending the hill, a section near Eason shows:

1.	Gray sand	1 foot.
2.	Light cream colored clay	1½ feet.
3.	Lignitic material	8 inches.
4.	Laminated brown or peaty colored clay	3 feet.

Near Fant's a cut shows a deposit of brown sand and siliceous gravel, and from that place southward, as far as mile post 97, the general slope of the country is south, and covered with gray sand and siliceous gravel, the latter sometimes attaining a thickness of two feet. A section near mile post 97 shows a section of:

1.	Gray sand	2 to 6 feet.
2.	Gravel, consisting mostly of quartz, jasper and fossil wood	2 feet.

Twenty-five hundred feet south of the mile post an exposure, two hundred and fifty feet long, shows a fossiliferous limestone, from one and one-half to two feet thick, resting upon a gray indurated sand or soft sandstone. The following is the section:

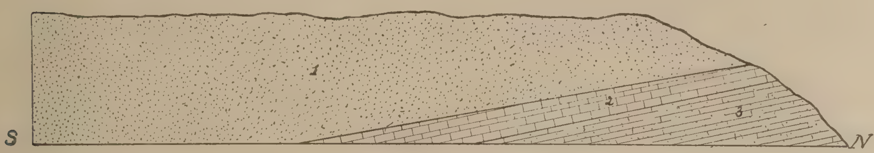

Fig. 6.
1. Gray sand. 2. Limestone. 3. Indurated gray sand.

1.	Gray sand	3 feet.
2.	Limestone containing casts of *Venericardia planicosta* (?) and other shells	$1\frac{1}{2}$ to 2 feet.
3.	Indurated gray sand or soft sandstone	4 feet.

This limestone is also found in a well two hundred yards southeast of the exposure on the line, dipping south 20 degrees east 3 degrees. The overlying sands of this section cover the country from this place to near mile post 96, where there is a section of:

1.	Gray sandy soil	1 foot.
2.	Brownish gray or yellow sandstone, gradually losing its brown tint as it nears the base. The upper brown division is thinly laminated and contains plant impressions and nodules of pure white clay. The lower gray division contains clay nodules but no plants	2 feet.
3.	Soft white sandy clay	$1\frac{1}{2}$ feet.
4.	Dark purple clay	4 inches.
5.	Gray sandstone	2 feet.
6.	Cross-bedded gray sands	8 feet.

No. 5 thickens toward the southeast.

From this point, southward, to Corrigan, the country is covered with a coarse gray sand.

5. SECTION FROM CORRIGAN EASTWARD TO COLMESNEIL ALONG THE LINE OF THE TRINITY AND SABINE RAILWAY.

This section passes through the counties of Polk and Tyler, the first ten miles being in a nearly east and west direction, and the last nineteen miles in an approximately southeastern course.

The gray sand seen at the termination of section 4, in the neighborhood of Corrigan, continues east for a distance of fifty-four hundred feet, when it gives place to a blue clay containing crystals of gypsum, probably a continuation of the deposit seen on the south side of the Neches river, near Clark's ferry. The clay is exposed for a distance of at least two hundred feet along the line, and is at least six feet thick. Eight hundred feet east of mile post 39 the blue clay is overlaid by a soft white siliceous earth, with an upper pink division, the section shown being:

1. Pink colored, wave-marked siliceous earth . . . . 4 inches.
2. White siliceous earth of the same structure as No. 1. . . . . $1\frac{1}{2}$ feet.

The dip of these beds is towards the southeast at a rate scarcely appreciable. Going eastward six hundred feet, the siliceous earth gradually changes into a coarse, much cross-bedded sand, showing a comparatively level stratum of white sand running along the top; and five hundred feet further east the cross-bedding disappears, and the bed becomes horizontally stratified until within one thousand feet of mile post 40, when the sand gives place to a fine white or pinkish white sandy clay, which a short distance further along the line is seen to be over six feet thick. Three hundred feet west of the mile post a few bowlders of gray sandstone overlie the clay, and at the mile post the surface of the ground is covered with gray sandstone bowlders and large pebbles, both of which are stained brown.

For the next one thousand feet the clay is seen lying between two deposits of gray sandy clay, or clayey sand, which unite and pinch out the unstratified clay at nine hundred feet.

Twenty-six feet west of mile post 41 the surface is covered by a ledge of gray sandstone ten inches thick, underlaid by the white clayey sand seen in the last section. This sandstone dips south 50 degrees east, and thickens towards the southeast. From this place to nine hundred feet east of mile post 41, the country is covered with white sand, and at the nine hundredth foot mark a small deposit of conglomerate occurs, made of gray sand and white siliceous pebbles. The white sands continue from here as far east as mile post 43.

One hundred feet west of mile post 45 the surface formation is a fine grained white sandstone, very much broken and of irregular thickness, varying from one to three feet. The lower division of this bed has a tendency to weather in a nodular form. This deposit thickens to the east, and in a creek three hundred feet south of the mile post is over ten feet thick.

Fourteen hundred feet west of mile post 47 the soft chalky siliceous earth is again seen in the bottom of the creek where the bank shows a section of:

1. Gray sand . . . . 10 feet.
2. Soft white stone or siliceous earth, visible . . . . 1 foot.

These deposits dip at a very small angle toward the southeast, or very nearly with the course of the road, which is here south 50 degrees east.

This portion of the road runs through a low marshy piece of country, which is evidently the result of very extensive denudation or erosion. On either side of the road, at a distance of one-fourth to one-half mile, this flat land is flanked by comparatively steep-sided conical hills of white sandstone, rising forty to one hundred feet above the level of the road. These hills are connected by a continuous stratum of heavy bedded white sandstone underlying the marsh, and which appears in the bottom and sides of the present creek wherever it has cut deep enough to lay the sandstone bare. A hill, one thousand yards south of mile post 46, rises abruptly above the level of the road, and is altogether made up of these sandstones. The deposits at the base are from two to three feet thick, but in ascending the hill they gradually become thinner and more flaggy, until at the top they do not present a thickness greater than one to two inches, and are whiter than the beds towards the base. The thin flaggy sandstones forming the upper strata contain numerous casts of plants, chiefly reeds, marsh grasses and the Sabal, of which last, the specimens found show an immense width of leaf, some of them having a stretch of from two and one-half to three feet. A fragmentary deposit of sharp siliceous sandy conglomerate overlies these sandstones, and crowns the highest points of the hills on the south of the line.

At Bowers the sandstones are overlaid by a broken, drab colored, clayey sand, and at one thousand feet west of mile post 48 the section shown is:

1. Gray sand . . . . 2 feet.
2. Gray sandstone . . . . 2 feet.

A gully at mile post forty-eight again shows the sandstone underlying a thin stratum of red or brown pebbles. Here the underlying rock has become pale yellow in color. The gray sands cover up everything until within three thousand feet of mile post 50, and at three hundred feet west of the mile post this gray sand gives place to a mottled red and blue sand.

Going eastward from mile post 51 a section twelve hundred feet south shows:

1. Dark gray sandy soil . . . . 1 foot.
2. Dark clay, containing nodules of lime in great quantities . . . . . . 8 feet.
3. Yellow sand . . . .

The blue clay, No. 2, is underlaid by a red clay on the south side of the ravine, and a complete section of the hill from the summit at mile post 52, looking northwest, is:

1. Surface gray sand . . . . 6 inches.
2. Brown mottled sand, dipping southeast 3 degrees, and disappearing one hundred feet south . . . . 2 to 4 feet.
3. Gray stratified sand, dipping southeast 15 degrees, and containing fossil palm wood in great quantities, with numerous quartz, jasper and other pebbles . . . . 20 feet.
4. Blue clay, partially stratified, but showing a tendency to break up into conchoidal blocks, and containing numerous nodules of calcareous matter . . . . 50 feet.
5. Red clay, having practically the same structure as No. 4, but without the limy concretions . . . . 10 feet.
6. Yellow sand visible on north side of ravine . . . . 4 feet.

On the south side of the hill No. 2 disappears, and No. 3 becomes the prevailing deposit. The fossil palm wood and pebbles become more plentiful, and lie scattered through the washouts along the sides of the railway cuts. At Fleming's the blue limy clay is seen in the cut, and the sandy clay continues to form the main deposit to Chester station, where it becomes a black soil, but still retains the lime in the form of concretions. Here the black soil rests upon a yellow clay.

Forty-two hundred feet east of mile post 54 a mottled sandy clay appears five feet thick, with pocket of red sand; and twenty-six hundred feet west of mile post 56 the same character of red sand occurs, underlying a gray sand containing stray fragments of palm wood. At the east end of a cut, eleven hundred feet east of mile post 56 the bank shows a section of:

1. Black soil . . . . 2 feet.
2. Black clay, inclosing nodules of lime . . . . 5 feet.
3. Stratified clay, dipping east at a small angle . . . . 6 feet.

Eighteen hundred feet east of the mile post the surface deposit is a gray sand which is shown in a section ten feet deep, and at twenty-one hundred feet the section is:

1. Gray sand, containing siliceous pebbles . . . . 10 feet.
2. White clay, visible . . . . 2 feet.

Going east to mile post 57 a section shown in a cut is as follows:

1. Gray sandy soil . . . . 2 feet.
2. Gray clay . . . . 1 foot.
3. Partially stratified mottled clay, containing nodules of white clay . . 12 feet.

Eighteen hundred feet further east, at the top of the grade, the section is:

1. Gray sand . . . . 1 foot.
2. Soft gray sandstone . . . . 2 feet.
3. Gray sand, same deposit as No. 1 of above section . . . . 7 feet.

At mile post 58 a washout shows a section of:

1.	Light grayish white sandy clay	15 feet.
2.	White sand	2 feet.

Twelve hundred feet east of mile post 58 a cut sixty feet long shows a deposit of brown and brownish gray sandy clay folded over a rounded exposure of white clay, and resting at each end on a deposit of white mottled sandy clay. This brown sandy clay extends eastward to mile post 59, where it is ten feet deep. Toward the eastern end of the cut this brown sandy clay has a tendency to lamination, dipping south 50 degrees east 15 to 5 degrees. One thousand feet east of the mile post the color changes to a light gray for some distance, and then becomes mottled. An exposure at mile post 62 shows a light gray sandy clay enclosing nodules of white clay.

One thousand feet east of mile post 64 a gully on the south side of the road shows a deposit of cross-bedded brownish white or gray sand, fifteen feet deep, containing great quantities of pebbles, forming a ridge extending northeast for over a mile.

Four thousand feet west of mile post 66 a cut, twenty-two hundred feet long, shows a section of mottled indurated sand or soft sandstone, cross-bedded at the west, but becoming more regularly stratified toward the center and through the eastern half. The dip is south 50 degrees east, but very slight. The upper surface of the brown sand is irregular and wavy in form, and at the east end is overlaid by an irregular series of deposits of pale blue clay, which in turn is overlaid by a pale blue sand. The following section is from the combined sections at various portions of the cut:

1.	Gray sand at east end	6 to 8 feet.
2.	Mottled blue clay, in small irregular elliptical pockets	6 inches to 2 feet.
3.	Mottled brown sand or soft sandstone, broken into irregular blocks, and containing lenticular patches of pale grayish blue clay, stratified at east end of cut, dip south 50 degrees east	10 feet.
4.	Gray cross-bedded sand, containing siliceous pebbles and fossil wood at west end of cut	15 feet.

6. SECTION ALONG THE SOUTHERN PACIFIC RAILWAY, FROM ROCKLAND TO SABINE PASS

This line extends south from the Neches river at Rockland, in Tyler county, to Sabine Pass, on the Gulf coast, in Jefferson county.

Rockland has an elevation of one hundred and thirty feet above sea level, and the country lying south of the river gradually increases in altitude until at Summit station, six and one-half miles south, the crest of the ridge attains a height of four hundred feet.

The gray sandstone found in the neighborhood of Stryker, on the Trinity and Sabine Railway, are here found occupying a position at the

very base, and forming an escarpment along the southern bank of the Neches river, a section of a quarry at Rockland showing:

1.	Gray sand	4 feet.
2.	Coarse grained gray sandstone	5 feet.
3.	Hard blue sandstone	15 feet.

The coarse gray sands forming the surface are evidently derived from the destruction of the overlying coarse sandstones. Sandstone hills occur throughout the neighborhood, and continue to be the material exposed in the cuts along the railway as far south as the sixty-ninth mile, or four miles south of Rockland, where they lie at an elevation of two hundred and seventy-five feet above tide. Here these sandstones are succeeded by a blue clay containing limy nodules, which is again overlaid by a series of blue, green, red and brown, and mottled clays, presenting the following section:

1.	Gray sand and siliceous pebbles	18 feet.
2.	Mottled blue and brown sandy clay	20 feet.
3.	Green sandy clay, very pale and watery in color	20 feet.
4.	Brown sandy clay	25 feet.
5.	Pale blue sand and clay	15 feet.
6.	Dark blue clay, containing limy concretions	20 feet.
7.	Drab gray sandy clay, becoming gradually the same as No. 8	30 feet.
8.	Gray sandstones, coarse grained on top, but changing to a fine grained blue stone at base	120 feet.

A section shown in a cut one mile south of Summit station gives:

1.	Light gray sand	2 to 4 feet.
2.	Conglomerate of siliceous pebbles in a ferruginous mattrix adhering to brown ferruginous sandstones, found in bowlder form and in connection with an irregularly deposited strata of ferruginous material. This bed changes toward the northern end to a brown or pale red sand, cross-bedded and interlaminated in places with lenticular shaped deposits of brownish blue clay	10 to 13 feet.

Occasional outcrops of brown sand, containing numerous siliceous pebbles, are seen underlying the gray sand forming the surface, from this place to near Colmesneil station.

The cut, through which the junction of the two railways is effected, shows a section of yellow and brown sand twenty feet in thickness, the brown sand containing nodules of pink clay.

The overlying yellow sand is apparently only the brown in a bleached condition. The region around Colmesneil is covered by this yellow or brownish yellow sand.

One thousand feet south of Colmesneil a cut fourteen hundred feet long shows a section, near the center, of:

1.	Gray sandy soil	1 foot.
2.	Brown unstratified sand	2½ feet.
3.	Stratified brown sand, with white streaks	4 feet.
4.	Pink colored clay	2 feet.
5.	Pinkish white sand	12 feet.

The stratification of these deposits is very irregular and broken, and the dip is alternately northwest and southeast. One hundred feet from the south end the pink clay and sand deposits break off abruptly, and the end of the cut is covered by the brown unstratified sand of No. 2 of the above section.

The pink colored clay is the same as the similarly colored clay found in nodular form lying amongst the yellowish brown sands seen in the cut, north of the station, through which the connection between the two lines of railway is made. Four hundred feet south of the first mile post south of Colmesneil, a cut shows eight feet of a brown, partially stratified sand, in which the lines of stratification are southeast 20 degrees; and one thousand feet further south is a section of:

1.	Gray sand	4 feet.
2.	Brown sand	1 to 6 feet.

Near the north end of this cut the partially stratified brown sand is seen in a gully underlying No. 2, and twenty-two hundred feet further south a small patch of this brown sand appears under a gray sand showing small outcrops of clay, and fourteen hundred feet still further south a section shows the stratified brown and blue sands changing into a mottled sand, dipping south 40 degrees east 8 degrees. Two and a half miles south of Colmesneil this section occurs:

1.	Brown sand, partly stratified	4 feet.
2.	Blue clay, containing limy nodules	20 feet.
2.	Brown sand, in gully at north side of hill, stratified	10 feet.

Half a mile further south another cut shows the upper two members of this section only. The brown sand is three feet thick, and the blue clay eight feet.

Three and one-half miles south of Colmesneil a cut eight hundred feet long shows a section of:

1.	Gray sandy soil	1 foot.
2.	Brown clayey sand	4 feet.
3.	Brown laminated sand, dipping south 40 degrees east 5 degrees	3 to 10 feet.
4.	Brown sand, with pale blue clay streaks, dipping south 40 degrees east 8 degrees, and running out at four hundred and fifty feet	4 feet.
5.	Brown sand with a pinkish shade, ten feet at north end, running out at four hundred feet	1 to 10 feet.
6.	Thinly stratified blue clay and red sand, seen in north end of cut	6 feet.
7.	Blue clay with lime nodules, seen in gully at north end	6 feet.

This blue clay, No. 7, is apparently the same bed as seen overlying the gray sandstones on the north side of the hill at Summit and in the other sections southward as far as the last. It is last seen about two miles north of Woodville, but occurs in wells at that place, a section of a well at Woodville showing:

1.	Yellow sandy loam	30 feet.
2.	Blue clay	6 feet.
3.	Brown and yellow sand	4 to 14 feet.
4.	Clay	

One thousand feet south of the first mile post south of Woodville a small cut shows a section of:

1.	Mottled sand	6 feet.
2.	Mottled clay	2 feet

And two miles north of Seneca the general section is:

1.	Brown sand	3 feet.
2.	Bowlders of gray sandstone, stained brown	. . .
3.	Brown sand, containing white nodules	6 feet.

From here to half a mile south of Seneca the sands are mottled red and blue, changing first to a pinkish hue, and then white, with small red spots running through the white, and having a yellow or orange tint on the top of some of the higher points. One and a half miles south of Seneca a cut eighteen hundred feet long and fifteen feet deep in places shows a general section of:

1.	Yellow sand	2 feet.
2.	Mottled pink and white sand	2 feet.
3.	Brown sand	11 feet.
4.	Pink sand, showing near north end of cut	2 feet.

No. 4 is irregularly laid down, and appears in places throughout the cut, and near the center rises in a rounded form almost to the top. Ferruginous gravels and pebbles of quartz, etc., occur scattered through this deposit as well as in the brown overlying sand, No. 3.

From this place to one mile north of Hillister the country is hilly, the hills being generally of a rounded form. Great quantities of ferruginous and quartzose pebbles and gravel occur scattered throughout the region. One mile north of Hillister the mottled brown and white sand is again seen. This mottled coloring gradually changes to a white partially stratified sand, and again to a mottled sand. A section shows:

1.	Gray sand	3 feet.
2.	Mottled yellow sand	3 feet.
3.	Mottled brown and white sand, white for two hundred feet in center of cut	4 feet.

From here to Warren the line passes through heavy deposits of yellowish gray sand, and at Warren the only section seen is:

1.	Yellow sand	3 to 5 feet.
2	Mottled sand	2 to 4 feet.

Going south from Warren, the gray and yellow sands are seen about one mile south of the station. In this place a thin line of ferruginous gravel forms the parting between the two deposits.

Half a mile south of Hyatt the section is:

1.	Gray sand on top of grade, one mile from station	4 feet.
2.	Yellow sand, with great quantities of ferruginous gravel and pebbles	3 feet.
3.	Mottled sand	4 feet.

The gray sand continues from here to Long, and one mile south, near

the north side of Village creek, the gray sand appears underlaid by a mottled sand. A well at Long, thirty feet deep, shows a yellowish gray and mottled sand throughout its whole depth. On the south side of Village creek, and extending southward to near Plank or Nobles' station, a section shows:

1. Brown sand . . . . 2 to 10 feet.
2. Pale blue laminated clay, showing at different places through the cut, but heaviest at north end . . . . 2 to 4 feet.

The only other cut seen on this portion of the road is fifteen hundred feet south of Kountze station, where the section shows a yellow loamy sand with light gray spots, and slightly mottled in the lower division. The yellowish gray sand continues as far south as half a mile north of Pine Island bayou, where this section was seen:

1. Gray sand . . . . 1½ feet.
2. Blue and yellow streaked clay . . . . 5 feet.

On the north side of the bayou, near the ferry, the clay seen is a mixture of pink and blue, the blue largely predominating.

From Pine Island bayou to twelve miles south of Beaumont the country is a level prairie, underlaid by laminated blue clay, which is rarely seen, and southward from the prairie the country to the coast is a low flat region mostly marshy.

The only point of interest connected with this section is the occurrence of ferruginous gravel as far south as Hyatt, and the occurrence of the quartz pebbles, so plentiful throughout the northern portions of East Texas, at their most southerly point near Hillister, where they are found in profusion.

The sequence of the disappearance of the gravels in this region is remarkable, as being the reverse of that generally found elsewhere throughout Eastern Texas. In going southward the siliceous gravels disappear near Hillister, while ten miles further south the last of the ferruginous gravels occur. This would seem to indicate that somewhere toward the east there is a local origin for these ferruginous pebbles.

ELEVATIONS OF STATIONS AND OTHER POINTS ALONG THE LINE OF THE FOREGOING SECTION.

Station.	Elevation.	Authority.
Terrell	515	Texas and Pacific Railway.
Contact between Cretaceous and Tertiary	500	Texas and Pacific Railway. Texas and Pacific Railway.
Burnett Hill	546	Texas and Pacific Railway.
Muddy Cedar	465	Texas and Pacific Railway.
Elmo	510	Texas and Pacific Railway.
Cobbs	510	Texas and Pacific Railway.
Rocky Cedar	490	Texas and Pacific Railway.
Wills Point	530	Texas and Pacific Railway.
Edgewood	460	Texas and Pacific Railway.
Stevenson	465	Texas and Pacific Railway.
Bolton Switch	460	Texas and Pacific Railway.
Grand Saline	408	Texas and Pacific Railway.
Silver Lake	370	Texas and Pacific Railway.
Sabine river	310	Texas and Pacific Railway.
Macks	380	Texas and Pacific Railway.
Mineola	415	Texas and Pacific Railway.
Mineola	421	International and Great Northern Railway.
Sabine river	312	International and Great Northern Railway.
Railway tank north of Lindale	420	International and Great Northern Railway.
Lindale	547	International and Great Northern Railway.
Swann	491	International and Great Northern Railway.
Hill west of Swann	600	International and Great Northern Railway and by barometer.
Tyler	525	International and Great Northern Railway.
Tyler, International and Great Northern Railway crossing	610	Tyler Southeastern Railway.
Ashcraft	530	Tyler Southeastern Railway.
Flint	560	Tyler Southeastern Railway.
Bullard	540	Tyler Southeastern Railway.
Mount Selman	730	Tyler Southeastern Railway.
Smyrl	740	Tyler Southeastern Railway.
Jacksonville	530	Tyler Southeastern Railway.
Jacksonville	525	International and Great Northern Railway.
Independence	500	Tyler Southeastern Railway.
Dial	540	Tyler Southeastern Railway.
Bradshaw	570	Tyler Southeastern Railway.
Rusk	540	Tyler Southeastern Railway.
New Birmingham	600	Tyler Southeastern Railway.
Linwood	580	Tyler Southeastern Railway.
Stephens	460	Tyler Southeastern Railway.
Alto	460	Tyler Southeastern Railway.
McBee's school	460	Barometric measurement based on Tyler Southeastern Railway line.
Coal Camp	380	Tyler Southeastern Railway.
Comer	300	Tyler Southeastern Railway.
Forrest	300	Tyler Southeastern Railway.
Wells	350	Tyler Southeastern Railway.
Bodan	360	Tyler Southeastern Railway.
Baker's	380	Tyler Southeastern Railway.
Clauson's	400	Tyler Southeastern Railway.
Lufkin	350	Tyler Southeastern Railway.
Lufkin, crossing Houston East and West Texas Railway	326	Houston East and West Texas Railway.
Burke	270	Houston East and West Texas Railway.
Neches river	150	Houston East and West Texas Railway.
Top of ridge	270	Houston East and West Texas Railway.
Eason	250	Houston East and West Texas Railway.

ELEVATIONS OF STATIONS, ETC.—continued.

Station.	Elevation.	Authority.
Fant's	220	Houston East and West Texas Railway.
Corrigan	220	Houston East and West Texas Railway.
Corrigan, at Trinity and Sabine Railway crossing	233	Trinity and Sabine Railway.
McMann's creek	185	Trinity and Sabine Railway.
Stryker	207	Trinity and Sabine Railway.
Bowers	263	Trinity and Sabine Railway.
Mulvey	240	Trinity and Sabine Railway.
Fleming	227	Trinity and Sabine Railway.
Chester	245	Trinity and Sabine Railway.
Russell's creek	217	Trinity and Sabine Railway.
Skidway	282	Trinity and Sabine Railway.
Mobile	200	Trinity and Sabine Railway.
Colmesneil	300	Trinity and Sabine Railway.
Rockland	125	Southern Pacific Railway.
Summit	400	Southern Pacific Railway.
Woodville	230	Southern Pacific Railway.
Seneca	250	Southern Pacific Railway.
Hillister	190	Southern Pacific Railway.
Warren	150	Southern Pacific Railway.
Hyatt	120	Southern Pacific Railway.
Village Mills	110	Southern Pacific Railway.
Long	110	Southern Pacific Railway.
Village creek bridge	70	Southern Pacific Railway.
Nobles	115	Southern Pacific Railway.
Tryon	110	Southern Pacific Railway.
Olive	100	Southern Pacific Railway.
Pipkin	100	Southern Pacific Railway.
Kountze	90	Southern Pacific Railway.
Nona	70	Southern Pacific Railway.
Weiss	65	Southern Pacific Railway.
Hook's Mills	40	Southern Pacific Railway.
Concord	35	Southern Pacific Railway.
Pine Island bayou	0	Tidal water, Southern Pacific Railway.
Beaumont	25	Southern Pacific Railway.
Sabine Pass	5	Southern Pacific Railway.

REPORT

ON THE

GEOGRAPHY, TOPOGRAPHY, AND GEOLOGY

OF THE

LLANO ESTACADO OR STAKED PLAINS

WITH NOTES ON THE

GEOLOGY OF THE COUNTRY WEST OF THE PLAINS

BY

W. F. CUMMINS.

REPORT

ON THE

GEOGRAPHY, TOPOGRAPHY, AND GEOLOGY

OF THE

LLANO ESTACADO OR STAKED PLAINS.

BY W. F. CUMMINS.

The name Llano Estacado, or Staked Plains,* is applied to the high

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*ORIGIN OF THE NAME.—The origin of the name, "Llano Estacado," or "Staked Plains," is not definitely known. There are a number of traditions, but after having examined thoroughly every one I could hear of, and failing to establish the authenticity of any one of them, the matter still remains in doubt.

Mr. Kendall, who traveled with the Santa Fe expedition from San Antonio to Santa Fe, in 1842, and afterwards wrote and published a report of the expedition, says: "This Plain was called Llano Estacado (Staked Plains) by the New Mexicans." (Vol. I, p. 219.) He gives no information, however, as to the origin of the name.

Captain R. B. Marcy says: "I was told in New Mexico that many years since the Mexicans marked out a route with stakes across this Plain where they found water; and hence the name by which it is known throughout Mexico of El Llano Estacado or Staked Plains." (Marcy's Explorations of Red River, p. 92.)

Captain Marcy gives no date where, nor direction in which this route was staked out, and so there is no way to verify his report.

In the Pacific Railroad Reports, Vol. II, p. 8, in a report made by Captain Pope, he says: "Upon the eastern or left bank of the River Pecos commences the Llano Estacado, or Staked Plains, which derives its name from an early tradition that in early times the Spaniards staked a road on it from San Antonio, Texas, to Santa Fe, in New Mexico."

There is no authentic information that there ever was such a road staked off, by the Spaniards or anybody else, between those two places across the Plains, but the route of travel was down the Rio Grande, and it is not probable that such a road was made, for the reason that a much better way, with plenty of water, could be found along the Pecos river.

In "Notes Taken," by Parker, p. 161, he says: "It is said that formerly a road was staked off across the Plains by the old Mexicans for the use of traders, hence its name."

He does not give any date or direction in which the road was supposed to run, so there is no means of testing the truthfulness of this tradition.

In a circular issued by the Union Pacific Railroad, the writer says: "It is related that the fathers, in 1734, *en route* from Santa Fe visiting San Saba, set up stakes with buffalo heads, so that others might follow the trail, and hence the name."

This statement is probably taken from Thrall's History of Texas, who says, on p. 23: "It is conjectured that in 1734, when the fathers from Santa Fe visited San Saba to establish a fort and mission, they set up stakes with buffalo heads on

plateau in the northwestern part of Texas and eastern New Mexico. It is situated between 100 and 103 degrees west longitude and 30 and 35 degrees north latitude. The plateau terminates abruptly on three sides, the east, north and west, in bold, precipitous escarpments ranging in height from one hundred and fifty to four hundred feet. On the south

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them, so that others might follow their route. This gave the name Llano Estacado to the plateau crossed."

As the mission and fort of San Saba was not established until 1757, and not by the fathers from Santa Fe, but by the fathers from what is now the eastern part of Texas, this conjecture can not be true.

In a recent private letter from Amando Chaves, Superintendent of Public Instruction of New Mexico, he says: "It is reported that a party of Spaniards, who had come to this country for the purpose of mining for gold, made a camp near where old Fort Sumner is now situated, and not finding any gold, they got in very destitute circumstances, and when a party of Comanches came from their hunting grounds somewhere to the east, part of the Spaniards returned with them to get supplies, and after securing a quantity of dried buffalo meat they undertook to return to their camp on the Pecos, when they became bewildered on the Plains, and separated into different parties. One of the parties reached the camp, and on returning to hunt for and assist their lost comrades, they loaded some of their mules with stakes, and at given distances set up stakes and surrounded them with mounds of earth, so that they might be enabled to retrace their steps, and in this way the Plains came to be called the Llano Estacado."

As no dates are given, nor the exact direction in which this road was made, there can be no particular certainty attached to this tradition from the "Oldest Inhabitant."

In 1540, Coronado went into winter quarters on the Rio Grande, near the mouth of the Pecos river. In 1541 he crossed the river and traveled in a northeast course on to the Plains, and continued probably as far north as Kansas. On the way he saw a great many buffalo and prairie dogs and found Indians living in tents of skins.

That route would have taken him only across the lower plains, and where he would have encountered the buffalo in the vicinity of Big Springs, and that may have been then, as it was afterwards, the hunting-grounds of the Comanche Indians. That tribe, in later years, occupied a large district of country and had their principal towns along the upper Red River. The range of the buffalo was never much south of Big Springs, and did not extend further than sixty or seventy miles west of the eastern escarpment of the Staked Plains.

Now if these Spaniards established their camp, as Mr. Chaves suggests, in the vicinity of where Fort Sumner was afterwards built, in order to reach the hunting grounds of the Comanches a part of the Plains would have had to be crossed over, which would give to the tradition some plausibility.

In Coronado's journal of his trip, in 1541, he speaks of crossing a great plain where there were a great many oxen with bent backs, and small animals living in burrows in the ground, and that the Indians killed many of these oxen and made tents of their skins. He further says that there were no trees by which to make their way, and in order that they might be able to find their way back if necessary, they built great heaps of ox dung to mark their way. This may have given rise to the name or to the tradition that is still held in New Mexico that on an expedition to the Indian country they carried stakes and set them up.

Another theory has been given by Mr. J. W. Hawes in the American Encyclo-

SCARP OF STAKED PLAINS AT BLANCO CANYON.

side the descent is more gradual, and the boundary not so well defined. It is but a remnant of a once very extensive area, reaching from its present terminus on the south far to the northward, and from the Guadalupe mountains on the west to an unknown shore-line east of its present limit, as is clearly indicated by the extensive plains now lying north beyond the Canadian river, east between the headwaters of the Colorado, Brazos and Red rivers, and west beyond the Pecos. At present the plateau extends irregularly one hundred and sixty-five to two hundred miles from east to west, and about two hundred miles from north to south.

The following is a more definite statement of the boundary of the area,

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pedia, 1881, p. 670, who says: "The Llano Estacado or Staked Plains (so called from the great abundance of Yucca stems resembling stakes) extends from the Rio Pecos, in New Mexico, on the west, to the headwaters of the Colorado, Brazos and Red rivers on the east, and from the valley of the Canadian on the north to the Pecos on the south."

This theory will not bear the test of examination, for the simple reason that the Yucca plant with its stake-like stems does not grow upon the high plateau of the Staked Plain, but is very abundant west of it.

Another tradition is this, given in a communication published in the Dallas News:

"The Indians crossing into New—then a part of Old—Mexico in any kind of weather used neither guide nor compass, but the Mexicans attempting the same in buffalo hunting and trading expeditions would invariably get lost and frequently perish. To avoid this they drove down a stake—estaca—at the edge of the plain, another further on, from which the first could be plainly seen, and so on, *ad infinitum*, so that they could retrace their path in case they found no water. * * * Of course after the trails by the principal water holes became distinctly worn the stake system was discontinued, but the name survived. I was told this by an old Mexican living at Puerto de Luna (Door of the Moon) and who had crossed the Plains long ere Stephen F. Austin ever set foot on Texas soil."

Yet another theory is that it was so named from the fact that there are high escarpments on three sides of it, which at a distance have the appearance of huge fortifications.

It is suggested that the word from which our Staked Plains is derived is not the one that was originally used. That instead of Llano Estacado it ought to be Llano Estacada. Estacado is the perfect participle of estacar, which means staked plains. Estacada in the Spanish language means a palisade, and it is supposed that the term was used in reference to the Staked Plains in the accommodated sense in which we use the term palisade in the English language.

It is supposed that the two words became confounded and changed at some later period, and that some one in attempting to explain the origin of the then used term estacado invented the theory of putting stakes across the Plains as guides.

No matter what may have been the origin of the term, nor whether the name has been properly handed down as originally used or not, the name Llano Estacado or Staked Plains has been so long used and so well established in the literature of the country that it would be useless to attempt to substitute another name now.

taken from observations made during the past year's field-work: Beginning at Big Springs, in Howard county, north to Gail, in the center of Borden county; thence north to Double Mountain Fork of the Brazos, near where the west line of Garza county crosses the river; thence northwest to Salt Fork of the Brazos, near the south line of Crosby county; thence northeast and north, passing fifteen miles west of Matador, passing Connellee's peak, and crossing Pease river to the Quitique ranch. At ten miles further north the foot of the Plains turns almost abruptly west, caused by the erosion of the Palo Duro canyon. The high plateau can be seen to the northwest at about twenty miles distance; thence almost directly north, crossing the Fort Worth and Denver City Railroad at Goodnight, and thence north to a few miles south of the Canadian river; thence turning westward parallel with the Canadian river and at a distance of from ten to twenty miles from it, trending southward to the west line of Texas, in Oldham county; thence a little south of west to a point south of Tucumcari mountain, in New Mexico; thence westward about twenty miles to the northwest corner of the plains; thence a little east of south, parallel with the Pecos river, and at a distance of twenty-five to thirty miles east of it, to the Horsehead crossing, at the southeast corner of Ward county.

Within these limits is embraced the territory of the Staked Plains, except that of the southern extension, which can hardly be determined, from the fact that the surface of the country descends so gradually in that direction.

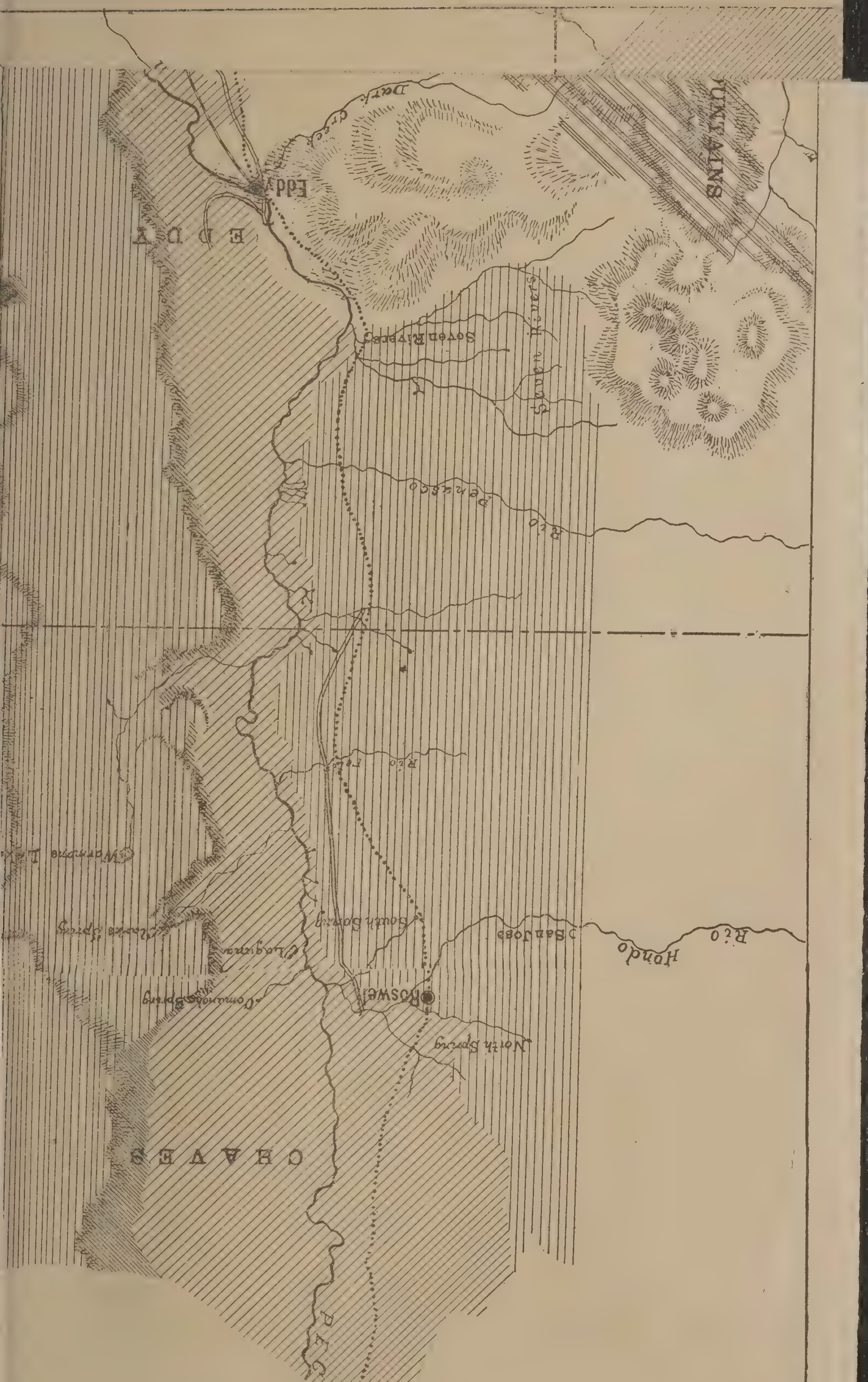
On the map, Plate No. IV in this report, the boundary of the Staked Plains is indicated, but it is intended only to give a general idea of it. The exact lines could not be drawn without an accurate topographical survey, which we did not attempt to make.

TOPOGRAPHY.

The Staked Plains is one immense plateau with a gentle inclination from northwest to southeast. It is so level apparently as to produce the peculiar appearance of being up-hill in every direction, and its inclination is only determinable by instrumental measurements. The following altitudes show the gradual slope:

Clarendon, east of the northeast corner of the Plains	2734 feet.
Amarillo, on edge of Plains in northeast	3630 feet.
Top of Plains at Fossil creek, extreme northwest	4520 feet.
Top of Tucumcari mountain, west of last point	4720 feet.
Midland, in southeast, on Texas and Pacific Railroad	2780 feet.
Warfield, west of Midland, on Texas and Pacific Railroad	2875 feet.
Odessa, west of Warfield, on Texas and Pacific Railroad	2900 feet.
Duro, west of Odessa, on Texas and Pacific Railroad	3100 feet.
Monahan's, west of Duro, on Texas and Pacific Railroad	2600 feet.
Crossing on Pecos river, on Texas and Pacific Railroad	2590 feet.

Besides the canyons which traverse the Plains in several directions,


Eddy
E D D Y
Seven Rivers
MOUNTAINS
Rio Penasco
Rio Felix
Laguna
Comanche Spring
Roswell
South Spring
San Jose
Rio Hondo
North Spring
C H A V E S
P E C

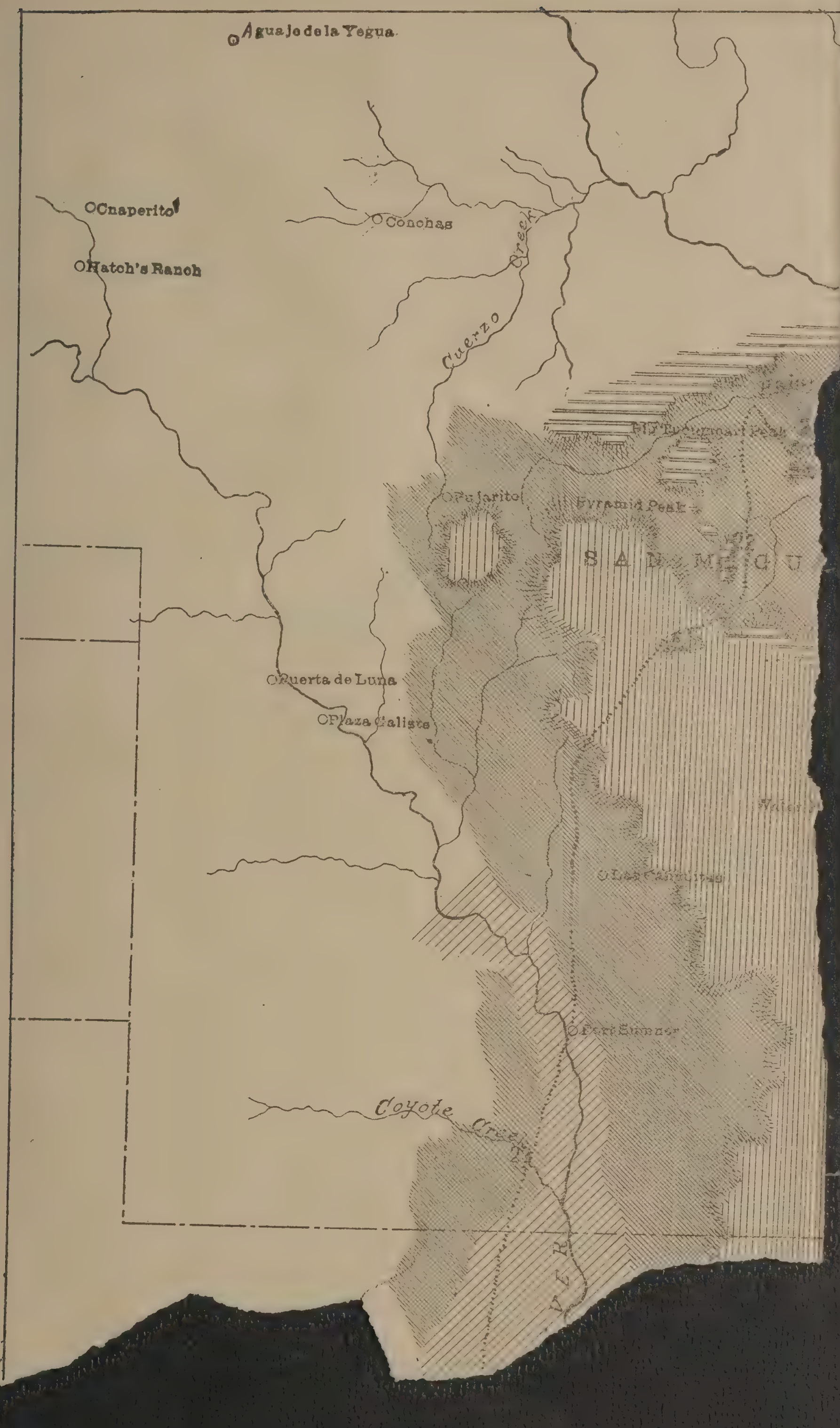
W. F. CUMMINS, GEOLOGIST FOR NORTHERN TEXAS.
N. F. DRAKE, ASSISTANT.

Irrigation Canals. Route. Quaternary and Recent. Tertiary. Cretaceous. Triassic. Permian. Carboniferous.

1 2 3 4 5 10 15 20 30 40 50 60 70 miles.

GEOLOGICAL MAP OF THE STAKED PLAINS AND ADJACENT AREA.

GEOLOGICAL SURVEY OF TEXAS. E. T. DUMBLE, STATE GE



there are several permanent lakes containing both salt and fresh water, and depressions in which rain water collects and stands for several months at a time. The only other diversity breaking the wide monotonous level are some drift sand-hills raised by the winds in the southwest.

CANYONS.

On the eastern side extensive canyons penetrate for various distances into the Plains, running from northwest to southeast, in line with the dip of the strata. The Colorado, Brazos and Red rivers all have their sources in the Plains with numerous branches extending a greater or less distance, some of them as far as one hundred miles. These canyons are the work of erosion, and no greater force was required than that now at work. When once the upper stratum is broken, and the water begins to flow over the soft material of the beds below, the channel is cut deeper each year, until the present deep canyons are the result. All have flowing streams in them, coming from the water-bearing stratum lying at the bottom of the Tertiary formation. Their sides are generally precipitous, so that at only a few places is it possible to cross them, even on horseback. Before roads were dug down one might travel for many miles without being able to cross.

SAND-HILLS.

About twenty miles west of Duro, a station on the Texas and Pacific Railroad, and south of the southeast corner of New Mexico, is a body of land known as the White Sand Hills. These hills extend from north to south about sixty miles, and are about fifteen miles wide. The whole area is covered with mounds composed of white quartz sand, rising in height from ten to thirty feet. They present steep ascents through short distances in many places, and the loose movable character of the sand and its depth render the passage of wagons through it next to impossible.

On approaching these hills from the east or west, they can be seen for long distances. The reason of their occurrence at this place and in their present form has not been determined. There are a great many lakes and ponds in these sand-hills, ranging in depth from three to five feet.

Their whole surface is covered with a growth of scrubby oak, known as "Shinoak," which now forms an obstacle against which the sand will and does deposit, and this may have been the original cause.

There are two probable sources of the material composing these hills —one of them the superficial covering of sandy soil that occurs almost everywhere on the Staked Plains, and the other the sandstones and sand that compose the underlying strata which are exposed at the surface southwest of this area.

GEOLOGY.

PREVIOUS WORK.

Nothing very definite has heretofore been determined of the geology of the Staked Plains. The various parties of observers who have traveled across the country in various directions, and who have seen it at different points, have reached different conclusions.

Professor Jules Marcou, in 1853, passed along the northern escarpment and across an arm of the highest plateau at one point. From the facts collected he concluded that the upper plateau was Jurassic, and so colored his map, published at a later day.

Professor Geo. G. Shumard, in 1855, passed across the extreme southern edge of the Plains and along the Pecos river to the mouth of Delaware creek. He reports only the Cretaceous, having collected a great many characteristic fossils of the Cretaceous period on his trip. He was geologist on the Marcy exploring expedition of Red River, in 1852, and saw the eastern escarpment of the Plains at the mouth and along Palo Duro canyon to its source. He placed the strata of the Staked Plains in the Cretaceous.

Wm. P. Blake made a report upon the geology of the route explored by Captain Pope, in 1854, near the thirty-second parallel. In speaking of that part of the route between Big Springs and the Pecos river he says: "The age of the overlying rocks of a lighter color are also obscure; but there is much reason to regard them as Cretaceous and Tertiary. The only fossils which I found in the collection from the Llano are Cretaceous, and serve to indicate the development of that formation at the Big Springs of the Colorado and a point on the Llano twenty miles east of the sand-hills."*

In the First Annual Report of the Geological Survey of Texas, 1889, I gave a brief mention of the strata of the Staked Plains under the name of Blanco Canyon Beds, and said: "The only fossils found in this bed were some of the larger mammals and a species of turtle. Enough was found to show the strata to be of much more recent date than the Cretaceous, which is found at the foot of the Staked Plains further southward."

In the Second Annual Report of the Geological Survey of Texas, 1890, in a further report under the name of Blanco Canyon Beds,† I stated that the strata was probably the equivalent of the Green river beds of Hayden." The intention was to say White river beds.

*Pacific Railroad Reports, Vol. II., p. 17, supplement.

†Since it is objectionable to have double names for formations, and for the further reason that the beds are found far from Blanco Canyon, I will hereafter designate them as the "Blanco Beds."

WORK OF THE PAST SEASON.

We began the work of the present season at a point on the San Saba river sixteen miles east of Menardville. This is the extreme southern outcrop of the Carboniferous formation in Central Texas, which is here composed of massive limestone in beds dipping to the southeast, containing the well known Carboniferous fossils *Productus punctatus*, *Productus costatus* and *Terebratula subtillita*. South of this locality the heavy beds of the Cretaceous overlie the Carboniferous.

Our route was westward along the valley of the San Saba river. About one mile from the place of beginning, the Carboniferous strata, which had been dipping to the eastward, changed their dip to the northwest, and at four miles, at the mouth of Crawford's creek, passed under the red clay beds of the Cretaceous. The following section was made here:

SECTION 1.

5.	Conglomerate	10 feet.
4.	Yellowish red clay	10 feet.
3.	Greenish sand	3 feet.
2.	Red clay	35 feet.
1.	Coarse grit	20 feet.
		78 feet.

No. 5 of this section is composed of rounded pebbles and larger bowlders, the latter of limestone and flints from the Cretaceous. The top of this bed is loose material, but has the same composition as the more firmly imbedded material in the calcareous matrix at its base.

No. 4. is a bright yellowish clay with some quartz sand.

No. 3 is a greenish sand of white rather large quartz sand.

No. 2 is a bright vermilion red clay, occasionally interstratified with a coarse siliceous grit.

No. 1 is a coarse massive grit of white and red quartz. This is not in regular layers, but only in isolated masses.

Plenty of timber along the river of pecan, overcup, elm and hackberry; mesquite in the valleys. Soils are black and reddish loams.

We continued up the valley of the river, crossing it twice, to the town of Menardville. The following section was made at a hill eight miles east of the town:

SECTION 2.

1.	Limestone, weathered into holes	6 feet.
2.	Yellow clay	8 feet.
3.	Limestone (with large gasteropods)	4 feet.
4.	Yellow sandy clay, with *Exogyra texana*	30 feet.
		48 feet.

From Menardville we went west along the Fort McKavitt road, crossing to the north side of the San Saba river, about four miles west.

The south side of the river, for several miles, shows a bluff of sixty feet. The whole section is massive limestone, slightly tinged with yellow, which is tough and makes a good building stone. It weathers very readily along some of the layers, the disintegrated materials being in heaps at the base of the precipice.

The section contains *Exogyra texana*, *Gryphœa pitcheri* (small), *Toxaster texanus*, *Pecten texanus*, *Arca*, *Trigonia*, and gasteropods, throughout the entire mass. The Gryphæas are more abundant toward the top.

Five miles from Menardville we took the San Angelo road, and at two miles, reached the top of the massive limestone. The hills are covered with shinoak brush, with an occasional open glade.

About six miles along the San Angelo road, on the top of a hill we found beds of flint, and further along, above the beds of flint, a stratum of limestone, in both of which were many Caprina.

Three miles east of Kickapoo Springs we passed over the water shed between the San Saba and Colorado rivers, going down the hill, over the flint bed and other beds of the Lower Cretaceous, to Kickapoo Springs. This spring comes from beneath a massive bed of limestone, and flows northward into the Colorado river. Above the massive limestones are several beds of fine grained sandstones, in neither of which were any fossils found.

On the hill beyond the spring we passed over a bed of very hard yellow Cretaceous limestone. The tops of the hills were again capped by the Caprina limestone for several miles. Eighteen miles from San Angelo we passed down the hills to Lipan Spring.

Four miles from Lipan Spring we quit the main road, and turned almost directly west along the northern base of the Cretaceous hills. At one mile after turning westward, a hill, rising to the height of eighty feet, is composed of beds of limestone, at the base of which is a bed of yellowish sandy clay with *Exogyra texana*.

We continued westward to the South Fork of Concho river, and after crossing, turned northwestward to the bridge across the Middle Fork of Concho river, and thence northwestward to north end of "Twin Peaks," about eight miles south 89° 15′ west from the courthouse at San Angelo.

The following section was made from the bridge on the Middle Fork of the Concho river to the top of Twin Peaks:

SECTION 3.

1. Smooth, evenly textured brownish limestone, none of the layers being more than two feet thick, and usually much thinner. Some of the thin layers break readily on weathering. Toward the top they contain a few *Pecten* and many *Caprotina* . . . . 10 feet.

2. Massive limestone, arenaceous, especially at the base. On weathering it breaks into angular fragments, and rough seamy boulders, the weathered surfaces usually yellowish. The layers graduate into each other, some weathering more readily than others. The following fossils were found in this bed: *Exogyra texana*, Roemer; *Gryphæa pitcheri* (small), Morton; *Toxaster texanus*, Roemer; *Pecten texanus*, *Lima wacoensis* . . . . 30 feet.
3. Yellowish sand, the top part being hardened and at places quite firm, but usually rough. Below the hardened layers are beds that fall to pieces readily on being exposed to atmospheric influences. Wood is the only fossil found in this bed . . . . 20 feet.
4. Bluish, yellowish, and white arenaceous clay containing crystals of selenite . . . . 20 feet.
5. Chocolate red clay so characteristic of the Permian in Texas. In this bed there is an occasional seam of soft sandstone, and thin seams of bluish clay . . . . 11 0 feet
6. Reddish, shaly, cross-bedded sandstone, which at places almost loses its shaly structure, and is quarried and used for building purposes. At places the rock is nearly white . . . . 4 feet.
7. Chocolate, red and blue clay. (In this bed occur salt wells and lakes) . 100 feet.
8. Irregular bedded reddish sandstone . . . .

The old town of Ben Ficklin is about three miles south of the town of San Angelo.

At the most southern quarry in that vicinity I made the following section:

SECTION 4.

1.	Limestone in layers	4 feet.
2.	Blue clay	3 feet.
3.	Red clay	10 feet.
		17 feet.

This section belongs entirely to the Permian, and in No. 1 there are numerous fossils.

Seven miles west of San Angelo, and just west of the mouth of Bald Eagle creek, in the bank of the river, the limestone is of the Permian outcrops, underlaid by blue clay. This is the most northwestern outcrop of the Permian beds along the North Concho river.

Fifteen miles from San Angelo I made the following section:

SECTION 5.

1.	Caprina limestone	20 feet.
2.	Yellow shaly limestone	6 feet.
3.	Massive limestone	20 feet.
4.	Yellow sandy clay (*Exogyra texana*)	30 feet.
5.	Sandy clay	10 feet.
6.	Sandstone	6 feet.
7.	Yellowish sandy clay	30 feet.
8.	Yellow sandstone	8 feet.
9.	Yellow sandy clay	30 feet.
		160 feet.

The following section was made twenty-four miles west of San Angelo, and one mile west of Water Valley:

SECTION 6.

1.	Caprina limestone	8 feet.
2.	Sandstone	3 feet.
3.	Sandy clay	6 feet.
4.	Hard fossiliferous limestone	3 feet.
5.	Hardened packsands, fucoidal	6 feet.
6.	Yellow clay	8 feet.
7.	Sandy clay, (*Exogyra texana*)	8 feet.
8.	Sand	30 feet.
9.	Purple clay	20 feet.
		92 feet.

About one-fourth of a mile north of this section the same strata occurs, but with one hundred feet of chalky limestone beds, containing nodules of flint, resting upon the top of the Caprina limestone.

The high Cretaceous hills east of the town of Montvale form both sides of the river valley, which is here two miles wide. One mile west of Montvale we left the river valley, turning in a northwestern direction along the Colorado City road, with the high Cretaceous hills on both sides of the dry creek up which we traveled.

After passing over a high table land, the dividing ridge between the waters of the Concho and Colorado rivers, we reached the sandstones and conglomerates of the Triassic, underlaid by the red clays of the Permian.

The sandstones on the south side of Girard creek are full of scales of mica, similar to much of the sandstone found everywhere in the Triassic.

We reached the Texas and Pacific Railroad at Westbrook, and turned westward along the railroad to Iatan. At that place we made the following section:

SECTION 7.

1.	Conglomerate	40 feet.
2.	Cross-bedded sandstone	12 feet.
3.	Red clay	23 feet.
4.	Micaceous sandstone	6 feet.
5.	Chocolate clay	40 feet.
		121 feet.

The following section was made at Signal Peak:

SECTION 8.

1.	Caprina limestone	35 feet.
2.	Massive hard white limestone	40 feet.
3.	Arenaceous limestone	55 feet.
4.	Compact white sand	20 feet.

5.	Soft massive sandstone	50 feet.
6.	Massive and cross-bedded sandstone	25 feet.
7.	Chocolate red clay	80 feet.
		305 feet.

Having reached Big Springs, we traveled northwestward about forty miles to Sulphur Springs, the entire way being over the broad level plateau with no exposure of the strata. At the Springs is a hard opalized layer of stone containing irregular shaped, rather small fragments of limestone.

From Sulphur Springs we went south to Marienfeld. About five miles south of Sulphur Springs we ascended an escarpment of the Staked Plains facing the northeast. Half way to the top is a bed of Cretaceous fossils, *Gryphæa pitcheri.*

About two miles east of Marienfeld is an escarpment about fifty feet high facing east. The base of this escarpment is red clay and red shaly sandstone. Above this is about ten feet of sandstone containing enough siliceous pebbles to be almost a conglomerate. This sandstone very much resembles the Trinity sands of the Cretaceous. It is mostly composed of fine white grains with a few scattering red ones, slightly cross-bedded at places, friable, but in regular layers, and not a solid mass of compact sand.

Above this to the top of the escarpment, is about ten feet arenaceous calcareous conglomerate. There is generally more sand than lime in the mass of rock, though at places it seems to be almost a limestone. The pebbles in it are usually white or colored siliceous pebbles, with an occasional piece of sandstone, iron conglomerate, and concretions.

There is also at the top, thin seams like opalized silica, also pebbles and bowlders of a hard flesh colored to purple siliceous stone resembling that seen at the base of the Tertiary at Iatan.

About six miles northeast of Marienfeld the Tertiary escarpment has changed but little from that just described. The cap rock is a little thicker, more massive, has almost lost its conglomeritic structure, and the opalized bed is thicker. Still further northward, five or six miles, the escarpment is not so marked, but slopes off towards the flats more gently, and the cap rock again becomes conglomeritic.

From Big Springs we travelled eastward for several miles, and then turned a little west of north in the direction of Gail, in Borden county.

At the head of Morgan's creek, in the north part of Howard county, is a small canyon that shows a good outcrop of the Tertiary strata overlying the red clays and sandstones of the Triassic. About ten feet of friable cross-bedded conglomerate rests upon the Triassic, containing many colored siliceous pebbles and water-worn *Gryphæa pitcheri* and a few *Exogyra texana*. Pieces of Permian sandstones are found in it, but no Tertiary material, so I conclude this is a Tertiary con-

glomerate. The cross-bedding is generally to the east. Above this conglomerate is thirty feet of compact reddish sand composed of white and many red grains, and containing some clay. Near the top is two or three feet of harder concretionary rock like the stone capping east of Marienfeld, and above this a capping of six feet of hard, white, brittle, rough or uneven textured, siliceous rock, containing masses of opalized silica. In places the silica is transparent. Red grains of sand give the rocks in places a reddish color.

Going north over this Tertiary plain, about four miles, we pass down on the north side into the valley of the Colorado, and find the Triassic red clay and micaceous shaly sandstones. One mile north of the Colorado river is a Triassic escarpment facing south, capped with four feet of white, massive and shaly, rather soft, and slightly micaceous sandstone. The top is a coarse grit. Compact white sand, about two feet thick, underlays this, and is in turn underlaid by a white argillaceous and gypsiferous sand, which graduates rapidly to the red clay below.

The following is a section made at Muchakooyo Peak, four miles east of Gail:

SECTION 9

1.	Limestone (Tertiary)	5 feet.
2.	Caprina limestone	35 feet.
3.	White argillaceous limestone	30 feet.
4.	Trinity sand	20 feet.
5.	Red clay	75 feet.
6.	Greenish sandstone	5 feet.
7.	Red clay, blue at base	50 feet.
8.	White and gray sandstone	10 feet.
9.	Red clay	30 feet.
		260 feet.

Gail, the county seat of Borden county, is situated at the foot of the high escarpment of the Staked Plains.

The following section was made one mile west of the town:

SECTION 10.

1.	Caprina limestone	10 feet.
2.	Soft limestone, white	20 feet.
3.	Massive limestone	15 feet.
4.	Massive limestone (building stone)	10 feet.
5.	Bluish clay	20 feet.
6.	Yellow clay (*Gryphæa* bed)	4 feet.
7.	Pack sand, gravel at bottom	40 feet.
8.	Micaceous sandy clay	20 feet.
9.	Red clay	61 feet.
		200 feet.

From Gail we went along the Lubbock road, a little west of north, for nine miles. Then leaving the road we traveled over the prairies

directly north, to the head of a small creek, where the hills are one hundred and fifty feet above the level of the surrounding country. They are composed of Tertiary and Triassic beds. The Cretaceous formation has entirely disappeared.

We found an old road leading into the breaks in a northeastern direction, which we took, and going down the hill and along the creek for three miles reached the broad valley of the Double Mountain Fork of the Brazos river. The water was standing in holes in the river, and as the sand was very deep in the channel we got plenty of water by sinking shallow pits in the sand. In the afternoon we crossed the river and two miles northwest found a large artificial tank of water. On the north side of the river is the high escarpment of the Staked Plains.

The following section was made at this place:

SECTION 11.

1.	White chalky limestone	40 feet.
2.	Red sandy clay, with concretions	30 feet.
3.	Conglomerate sand and lumps of clay	4 feet.
4.	Red clay	30 feet.
5.	White sandstone	8 feet.
6.	Conglomerate, fossiliferous	4 feet.
7.	Red and white spotted clay	30 feet.
		146 feet.

Nos. 1 and 2 of the above section belong to the Blanco beds, the balance to the Triassic. In number six (6) I found *Unios* that have not been described as far as I know. They came from a peculiar conglomerate composed of small iron and clay concretions very much like some of the conglomerates of the Permian. In the sandstones of the Trias are a great many scales of the mica, which is found everywhere in this bed of sandstone. The fossiliferous conglomerate is not uniform in thickness nor in the angle of dip, but thins out in places and dips in various directions. There is no timber here on the river, but some cedar on the hills and mesquite in the valleys.

We recrossed to the south side of the river, and went down on that side for six miles. On the south are the hills, 370 feet high, of Cretaceous material resting on the Triassic. One hundred and fifty feet of that is Cretaceous, with the Caprina limestone on top. The Trinity sands have thinned out very much, and there was no bed of siliceous pebbles at the bottom.

This ridge extends along the south side of the river for many miles, and then breaks into isolated peaks. The Double Mountains in Stonewall county are in the line of their extension, and it is probable they are but a part of a once connected ridge. The same fan shaped Caprina was found here as was taken at Double Mountains. This is the most

northern occurrence of the Cretaceous formation along the eastern escarpment of the Staked Plains.

We kept down the river for three miles, and then crossed to the north side where a fresh stream empties into the river. Continuing over the prairie for two miles, we reached a road leading from Snyder to Estacado and turned northwestward along that road for four miles, then turning north for three miles, reached Sandy creek. The sandstone of the Trias was seen in all the gulches on both sides of our road since leaving the river. On coming down the hill into Salt creek valley we pass over thick bedded micaceous sandstone.

In the head of one of the gulches a small spring was found, and water was obtained in the bed of Sandy creek by sinking shallow pits in the sand.

We continued along the old ranch road passing the hills of red clay and sandstone on both sides to the O. S. ranch. At this place there is a small spring coming out of the Triassic sandstone. We continued northward along an old road for a mile, and reached Yellow House canyon. The sand is very deep in the bed of this stream, but by digging shallow pits we found an abundant supply of water. Here our road ended, and we had to travel across a heavy sand ridge for a mile. On going down the hill on the north side we reached the south side of the Espuela pasture. Still having no road, we continued northward over heavy sand-hills to the Salt Fork of the Brazos, where we hoped to find fresh water, but were disappointed, for neither ourselves nor the stock could drink the water in the river, nor were the few springs we found issuing from the base of a heavy bed of conglomerate any better. The high sand-hills were on every side of us, but continuing still northward for a mile we saw an open prairie to the westward of our route, about a mile away, which seemed to lead out into the broad prairies beyond. We reached the narrow strip of prairie which opened up to the northwestward, in which direction we went for ten miles and reached McDonald's creek, where we found plenty of water, there having been a heavy rain at the foot of the Plains that evening and filling the holes in the creek with water that was only slightly salty.

We here found an old road leading in the direction of Dockum, on the south side of the creek, which we followed for three miles, when finding a cross road running northward we turned into that and traveled up the creek to its source.

Before reaching the head of the creek we passed through a gate into the pasture of the Kentucky Cattle Raising Company. There are several very fine springs at this place, which come from the sands at the base of the Tertiary strata.

We continued up the canyon two and one-half miles, and went up a steep hill to the top of the Plains, which at this place are very level

and stretch away as far as the eye can reach, without a single hill or hollow to break the monotony.

After reaching the top of the Plains we turned a little west of north to a windmill, where we got plenty of water. The company in whose pasture we now are traveling have put down quite a number of wells for the purpose of watering their stock. Those on the west side of Blanco canyon are about three hundred feet deep, and furnish an inexhaustible supply of good water, which is pumped by windmills into reservoirs, and there is always enough wind to keep an abundant supply. The water is first pumped into a large wooden trough, out of which the cattle drink, and the surplus runs into an open dirt tank, so that if at any time the water is exhausted in the trough there will be enough in the pool. This company first adopted the plan of storing the surplus water in wooden troughs, but they found that during a calm the water would be exhausted by the cattle drinking it, and the tanks would shrink on drying and leak very badly when again filled, and a great deal wasted; so they adopted the plan of making open dirt tanks for storage. The finest grass (curly mesquite) I have seen is in this pasture.

In some of the basins there is a grass known as "basin grass," which makes a very good hay.

Where we ascended the Plains there were round, water-worn, siliceous pebbles, and the angular masses of silicious limestone such as occur on the Double Mountain Fork and the Salt Fork of the Brazos river, and elsewhere along the foothills of the Plains.

We continued northward to Mt. Blanco, and descending into Blanco canyon made camp at the mouth of Crawfish creek, a small stream that flows into White river from the west side.

The following is a section of the strata one mile south of Mt. Blanco:

SECTION 12.

1.	Soil	8 feet.
2.	Limestone	2 feet.
3.	Sandstone	3 feet.
4.	Limestone, stalactitic	4 feet.
5.	White calcareous sandstone	4 feet.
6.	White sandy clay	30 feet.
7.	White diatomaceous earth	4 feet.
8.	Pack sand	20 feet.
9.	White diatomaceous earth	8 feet.
10.	Greenish sandy clay	30 feet.
11.	Red clay	2 feet.
12.	Reddish clay	3 feet.
		118 feet.

We found fossil vertebrates in Nos. 8 and 10 of the above section, but some curiosity hunters had been there and carried off nearly all the fossils, and those left were fragmentary.

We went north and took the road to Dockum, traveling thence in a southeastern course twenty-three miles, and made camp at the foot of the Plains near an old windmill, the same place at which we camped in the winter of 1889, as reported in the First Annual Report. The following section was made one mile north of this camp:

SECTION 13.

1.	White sandy clay	6 feet.
2.	White diatomaceous earth	3 feet.
3.	Purple clay	3 feet.
4.	White diatomaceous earth	4 feet.
5.	Reddish sandy clay	150 feet.
		166 feet.

In No. 1 of this section we found a fossil tortoise belonging to the Tertiary.

We moved camp to the Rock House, about eight miles northeast of Dockum, where we found a good spring issuing from the base of the conglomerate. One mile north of our camp is the following section:

SECTION 14.

1.	White limestone, top of plains	10 feet.
2.	Reddish clay	10 feet.
3.	Reddish sandy clay	180 feet.
4.	Cross-bedded sandstone	30 feet.
5.	Sandstone	8 feet.
6.	Conglomerate	11 feet.
7.	Red clay	30 feet.
8.	Conglomerate	6 feet.
9.	Sandstone, cross-bedded	10 feet.
10.	Conglomerate	12 feet.
11.	Red and blue clay	20 feet.
		317 feet.

Many years ago General McKenzie made a wagon route along the foot of the Plains leading almost north. As we intended to travel up the foot of the Plains, we took that old trail, and following up the creek on which we were camped to its source, again went to the top of the Plains, and, after traveling eight miles, descended on the eastern side and camped at an old ranch where there is a nice spring of fresh water.

In the valleys of all the creeks is a bed of Quaternary conglomerate, made up of material from the Triassic, Cretaceous and Tertiary, in which are found some very badly water-worn Cretaceous fossils.

Continuing northward along the old trail, crossing a number of small creeks with flowing water, we camped on Dutchman creek at a nice spring. Thence along the old trail to Cottonwood mott, a line camp of the Matador Cattle Company, which takes its name from a large grove of cottonwood timber in the vicinity. Several nice springs issue from the sands at this camp. Two miles beyond this place, at another creek,

we camped at a spring of fresh water. At this place the conglomerate rests upon the red clay, and very much resembles the formation at the Rock House northeast of Dockum. The country here is very much broken, and in places is covered with Quaternary drift.

We continued northward along the old trail, crossing a running creek, two plain roads, several sand-hills, down a steep rocky hill to a branch of Red River, and on down the north side of the stream, camping at the mouth of a small fresh water creek coming in from the west. Three miles west of this camp is the following section:

SECTION 15.

1.	Pinkish calcareous sandstone. This is the cap rock of the Staked Plains. The texture is uneven, and concretionary structure is common through it. The surface outcrop is full of fractures and openings of porous nature. Fragments cover the sides of the hill, and others are ready to fall off at the slightest jar	10 feet.
2.	Reddish argillaceous sand, with a few white concretions through it .	20 feet.
3.	Hard brittle pinkish sandstone. Lime concretions occur in places, but they are small and comprise a very small portion of the mass .	5 feet.
4.	Argillaceous sand. The amount of clay is generally very small, but sometimes there are thin bands almost pure. The sand is mostly white quartz grains, but yellowish, red, and black grains are seen scattered through it. They are stained in places by iron, and where a fresh outcrop is shown it generally has a mottled appearance of white and yellow. In the middle of the bed is a band of rather course sand and clay, ten feet thick, filled with well worn siliceous pebbles, hard micaceous sandstone, porphyry, granite and Cretaceous fossils. Some of the water-worn rocks are four inches in diameter. All this bed is compact, and weathers evenly where an outcrop is exposed	130 feet.
5.	White to gray micaceous conglomeritic sandstone, much cross-bedded, the layers dipping westward or northwestward and sometimes north. The water-worn pebbles are generally small; nearly all of the beds contain some of them, and about one half of rock is conglomerate made of this material. Small rounded pieces of hard brownish or dove colored clay frequently occurs in this stratum	85 feet.
6.	Red and rather soft sandstone and arenaceous clay, layers one to two feet thick. Layers of cross-bedded sandstone occur every eight or ten feet from the top downwards for thirty or forty feet, dipping northwestward	65 feet.

We continued along the old trail three miles, and passing over a spur of the Plains descended by a long slope to a broad level prairie extending many miles to the northward, going on to the Quitique ranch, on the south bank of North Fork of South Red River. The bed of the stream at this place is about one thousand feet wide. The sand is very deep in the channel, and, except in holes, no water was at the surface, but abundance can be had by digging pits in the sand.

We here took the Clarendon road for ten miles, to the breaks of Holmes creek.

The foot of the Plains is only two miles westward of this camp, and the section is about the same as the one last given, except number three, which does not occur at this place. At the base of the Tertiary there is ten or twelve feet of conglomerate containing some siliceous pebbles, a great many water-worn Cretaceous rocks, and some water-worn Cretaceous fossils, such as *Graphæa pitcheri* and *Exogyra texana*.

Continuing along the Clarendon road, for the first six miles the country is very broken—washed into deep gullies. We crossed Little Red creek, where the water was standing in pools and quite gypseous. In coming down the hill to the creek we passed over beds of massive gypsum. The lower beds here are Permian, and very much resembling the beds seen on Little Mud creek, twenty miles south of Dockum. The red clay in the gulches is cut in every direction by seams of fibrous gypsum. On ascending the hill, on the north side of the creek, we come upon a level plateau.

We reached Red River and made camp on the south side at the mouth of a creek of fresh water, where the river is about one thousand feet wide. The drift sand has blown into the channel and is very deep, and the drift sand-hills on the south side are from twenty-five to sixty feet high. The channel of Battle creek, a tributary running in from the west, is about three hundred feet wide at its mouth and filled with sand, with no water running. Three miles further on we crossed Mulberry creek about one mile above its confluence with the river. The bed of the creek was about four hundred feet wide, with a small stream of water running in it. The sand is very deep and the quicksand very bad.

We continued northward, about thirteen miles in all, over a succession of hills and broad plateaus to a creek, up which we traveled for three miles and made camp. We got water by digging shallow pits in the sand in the channel of the creek. This creek has its source in a high sand ridge on the north and in numerous gulches, in all of which are small springs of good water. There has been very heavy erosion along the country over which we have traveled since leaving Little Red creek, and only the lower part of the Tertiary is found anywhere and it is often entirely wanting. On the tops of the hills are water-worn siliceous pebbles. The water in the gulches comes from the base of the Tertiary.

We continued up the creek nearly to its source, and then passed up on a high plateau that extends to the Salt Fork of Red River.

There are two kinds of soil on this plain--a loose sandy soil, covered with a heavy growth of bunch grass and sedge grass; and a black sandy soil,

PALODURO CANYON.

covered with mesquite grass. It is a question among the settlers in this part of the country as to which is the best.

We passed through the town of Clarendon, and going westward four miles made camp on the Salt Fork of Red River near the old town of Clarendon, and at the mouth of a clear creek of fresh water that runs into the river from the south side. The water in the main river is salty. North of camp is a section showing red clay at base, above which is a bed of argillaceous red sandstone, which in turn is capped by three feet of hard, fine-grained limestone, weathering into sharp angular fragments.

From Clarendon we went westward along the railroad, up a gradual ascent that is scarcely perceptible, to Goodnight, a distance of eighteen miles. The top of the Staked Plains being here reached without a steep grade anywhere, while generally the eastern escarpment is very precipitous.

Mulberry canyon, three miles southwest of Goodnight, shows about the same Tertiary section as that we had seen through Dickens and Motley counties. The cap rock is not quite as hard as usual, and perhaps is more sandy. The argillaceous sand below contains many concretions, generally one to two inches in diameter. Fine black iron sand also occurs in this bed, as shown in the ravines that have cut through or into it. Water-worn pebbles, in a layer of three or four feet, occur about the middle of the section, and about ten feet of conglomerate of siliceous pebbles and water-worn Cretaceous fossils occur at the base of Tertiary sand. Just under this conglomerate there is four or five feet of hard, brittle, rough-surfaced sandstone, or almost a solid mass of silica of reddish color. The Triassic conglomerate does not occur here, and the siliceous rocks mentioned rest on red argillaceous sand that becomes gypsiferous at about forty feet from its top. The gypsum occurs in impure forms in massive layers and as intercalations through close seams in the bed.

The following section was made at Campbell's ranch, twenty miles south of Claude, in the Palo Duro canyon:

SECTION 16.

1.	Tertiary beds	115 feet.
2.	Cross-bedded conglomeritic sandstone	225 feet.
3.	Red and yellowish clay	135 feet.
4.	Vermilion argillaceous sand	90 feet.
		565 feet.

At the base of No. 1 is a bed of opaque, hard, brittle sandstone, two to three feet thick, which varies in color from a dull pink to white, in which translucent and transparent pieces occur in a few places. The bed of water-worn siliceous pebbles, containing a few water-worn Cretaceous fossils, occurs about sixty feet from the base of the stratum.

The remainder is a massive pinkish sand with nodules of clay and lime occurring through it. Towards the top of the stratum these concretions are mostly composed of lime, but elsewhere the quantity of lime is generally very small. About fifteen feet from the base of the stratum is a limy concretionary rock mass usually containing a large amount of brittle siliceous rock. When this is the principal constituent, the limestone is often found imbedded in the siliceous mass in an almost pure state, and so closely united with it as to show the bed is all of the same age. This bed varies in thickness from three or four feet to twenty feet. At the top of the Plains a brownish segregated banded limestone occurs to a limited extent, and small pieces of black carbonaceous limestone is frequently found near the top. This stratum is practically uniform for fourteen miles down the canyon, but is thicker on the north than on the south side. The springs of water along the canyon are found in this stratum, and it is the bed in which the water is found in all the wells on the Plains.

No. 2 of this section is a cross-bedded conglomeritic white sandstone occasionally interstratified with thin seams of bluish clay. Small flakes of mica are abundant, and fossil reptilian bones and coprolites are found. It contains no siliceous pebbles. The water-worn pebbles are usually a white argillaceous sandstone, though dark shades of brown and black occur, also pieces of shaly sandstone.

No. 3 is a bed of clay, slightly arenaceous, varying in color from purple to yellowish or yellowish red.

Nos. 3 and 4 show unconformability, the color and lithological character being quite constant. No. 3 has no stratification planes, while No. 4 is noted for them, and the contact between the two divisions is clearly marked and can be easily distinguished at a distance of a quarter of a mile, or as far as the beds can be seen. A thin layer of iron occurs in places near the base of No. 3.

No. 4 is a bright vermilion argillaceous sandstone, slightly shaly, and sometimes massive. Bluish white spots are common. The upper fifteen or twenty feet has very little or no gypsum, but from there to the base the gypsum rapidly increases in quantity until half or more of the material is massive gypsum, which predominates towards the bottom, where there are two layers from one to four feet thick, the bottom one being firm and beautifully banded.

An examination of the canyon below this point for a distance of fifteen miles showed this section to be about uniform at all places. On Home and Pleasant creeks stratum No. 2 was about two hundred feet thick, and on Hoppy creek it was about two hundred and thirty feet thick. Fossil wood and coal from drift logs occurred quite frequently in this stratum. Siliceous pebbles are extremely rare, and the relative amount of conglomerate sandstone and clay varies at different places.

By barometric measurement the top of the Staked Plains at Claude

is about one hundred and fifty feet higher than at the canyon. At the mouth of Dry creek the canyon is about six hundred and fifty feet deep, and gradually increased in depth towards the eastern escarpment of the Plains.

At the falls of Palo Duro canyon, south of Amarillo, the Tertiary beds are about one hundred and forty feet thick. Near the top there is often a bed of white arenaceous hardened clay, being sometimes more lime than clay, generally overlying a white argillaceous sand containing masses of stalactitic structure and fossil vertebrates. In this bed, on the south side of the canyon, opposite the falls, were found the teeth of a fossil horse and mastodon and other fragments of the skeleton. This sand bed varies in thickness from a few inches to fifteen feet.

A bed of siliceous pebbles and water-worn Cretaceous fossils occur at the base of the Tertiary. The fragments of Gryphæa seem to be different from the typical species of *G. pitcheri*, Morton. They are more dilate than the original type. The remainder of the Tertiary strata at that locality is about the same as seen at other places. It is composed of rather fine-grained white sand, with occasionally black and frequent red grains. There are also nodules of the sand in a matrix of clay, or clay and lime, the whole mass having a pink color and drift-like structure on the weathered surfaces.

Below this is a bed of about one hundred feet of Triassic material, partly conglomerate, but at least half or more a smooth, even-grained white sandstone. It is cross-bedded, the layers, from one to two inches in thickness, generally dipping a little north of west. It is made up of white and brown argillaceous sandstone fragments and a few fragments of limestone, all in a matrix of sand and crystalline calcite. It is generally quite hard, and the thicker layers make a good building stone. Fragments of *Unio* and reptilian teeth and coprolites were found in it.

Springs occur at numerous places at the top and middle of the conglomerate, being more numerous on the north than on the south side of the canyon.

There is about eighty feet of red, purple and yellow or blue clay underlying this bed of conglomerate, which in turn is underlaid by five feet of yellow, irregular textured, argillaceous limestone. Thin seams of crystalline calcite traverse this bed in every direction, and the concretions often contain crystals of calcite, but nodules are somewhat rare.

Two and a half miles northwest of Amarillo, at the base of the Staked Plains, is a quarry of sandstone belonging to the Triassic. The bed here is about fifteen feet thick. The stone is used for building in the town of Amarillo. Overlying this sandstone there is usually sufficient sand and clay to fill up the inequalities in the top of the

sandstones and conglomerates; then comes the characteristic basal Tertiary; then a bed of hard, brittle, pinkish siliceous stone, with grains of sand and often water-worn pebbles of limestone and quartz scattered through it. This siliceous layer, which is often conglomeritic, is about two feet thick. Above this bed, at this place, only fifteen feet of Tertiary strata is exposed. It is quite calcareous, and some of the Tertiary drift rock is a very dark carbonaceous limestone. Further back on the top of the Plains the water-worn pebbles are scattered over the surface in considerable quantities.

From Amarillo we went northwestward, passing off the high plateau of the Staked Plains, and travelling mostly over Triassic sandstones and Red beds, the sandstones, as usual, being full of scales of mica. The Red beds were generally covered with drift from the Plains. We crossed the west prong of Amarillo creek, and turned almost directly west, taking the road to the Frying Pan ranch. Before reaching there we crossed one or two small creeks with water from springs issuing from the base of the Blanco beds. At one of them is a small irrigated farm. At Frying Pan ranch a fine, bold spring of very cold water, issues from the base of the Blanco beds.

After passing the Frying Pan ranch, we followed the Tascosa road nine miles, where we reached the old Government road running from Fort Smith to Albuquerque, New Mexico. This is the route traveled by Professor Jules Marcou in 1853. Three miles further the Tascosa road turns to the northwestward. We continued along the old road almost directly west, and a mile further we found plenty of water in a deep pool, and camped.

We found upon examination that nearly all the small canyons in this vicinity, which extend into the Plains, have springs of fresh water in them, though it soon sinks in the deep sands of the valleys.

At this place the following section was made:

SECTION 17.

1.	Limestone, top of Plains	20 feet.
2.	Whitish sandy clay	30 feet.
3.	Coarse soft sandstone	6 feet.
4.	Red clay	10 feet.
5.	Soft sandstone	20 feet.
6.	Red clay	20 feet.
7.	Sandstone	6 feet.
8.	Red and white sandy clay	40 feet.
9.	Conglomerate and sandstone	8 feet.
10.	Reddish clay	30 feet.
		190 feet.

We continued along the old trail, crossing a number of steep hills and hollows, in which were streams of clear and running water coming from springs at the base of the Plains. We found in these hollows a

great quantity of wild grapes that were just ripening, and which were very sweet to the taste.

At five miles we ascended a steep hill to the top of the Staked Plains. At this place the plateau is very level and covered with a thick growth of mesquite grass. Three miles further we come to a large fresh water pond in a depression of the Plains. The water was derived from recent rainfall, and was not over four feet deep.

Five miles further we reached Encampment creek, which is nothing more than a deep canyon extending into the Staked Plains from the north from the Canadian river. The strata here is composed of the upper beds of the Tertiary and upper beds of the Triassic. The beds of the Triassic are much distorted and are composed of red clay, red sandstones and conglomerate. The conglomerate is composed of hardened clay and sand. The clay is very bright red. The water in the creek comes from springs at the base of the Tertiary.

We continued along the trail over the broad level plains for eighteen miles, and then went down off the Staked Plains at Rocky Dell creek. This creek comes from the Plains near where we descended, and has water standing in the holes in the sandstones.

Beneath a projecting rock on the bluff the Indians have carved and painted many crude figures in the sandstones.

The general appearance of the strata here is the same as at the other places noted along the northern escarpment—white, chalky limestone on top, and red clays and sandstones and conglomerates below. The sandstone is full of scales of mica, and is partly massive and partly laminated. The laminated part is dendritic. The conglomerate is very hard and resembles the upper bed at Dockum.

The highest point of the Plains passed over to-day was four thousand feet, by barometric measurement, above sea level. Our camp on the creek is three thousand seven hundred and eighty feet, giving two hundred and twenty feet as the height of the escarpment of the Plains at this place. Only about thirty feet of that is Tertiary and the balance Triassic.

We next camped on a creek about seven miles distant, near an old cattle pen, the foot of the Plains being about two miles south. The only perceivable difference in the strata of the Tertiary is that there appears to be more lime than has been seen before. Several windmills are in sight westward along the foot of the Plains. The wells are in the sandbeds, are not more than twenty feet deep, and furnish an inexhaustible supply of good water. Cedar in abundance grows along the bluffs of the Plains and cottonwood along the creeks.

Continuing along the old road, we crossed the State line between Texas and New Mexico. The country is more broken, but the strata is the same seen heretofore, with a number of sand-hills, caused by the drift from the Plains. Near the camp we found an exposure of sand-

stone and conglomerate. In the latter we found fragments of petrified wood, and in the red clay a fragment of a reptilian scapula. In the afternoon we came in sight of the top of Big Tucumcari mountain, which was visible from the top of the Plains the evening before, and is said to be fifty miles away.

About opposite, and a few miles north of the postoffice of Endee, we found some very badly water-worn *Gryphæa pitcheri*, Morton, in the creek.

We continued along the old road, and made noon camp at a pool of water in a ravine. Five miles before reaching this camp we saw for the first time the Tucumcari beds, which at that place formed part of the escarpment of the Staked Plains. The following section was made at that place:

SECTION 18.

1.	White limestone, characteristic limestone of the top bed of the Staked Plains	12 feet
2.	Hard limestone at base with grains of sand through it. This sand increases toward the top, where it is very little harder than compact sand	63 feet
3.	Coarse sand, with white grains and a few red grains intermixed	3 feet
4.	Bluish black shale, of uneven texture, with thin layers of argillaceous sandstone. This bed is highly fossiliferous; has *Gryphæa tucumcari*, Marcou; *Exogyra texana* and *Pecten texana*	12 feet
5.	Water-worn siliceous pebbles and sand	6 feet
6.	Fine compact sandstone, of uniform yellow color, weathering with a smooth surface	72 feet
7.	Alternating layers of red, bluish white and pinkish arenaceous clay and argillaceous sand, usually in thin layers	42 feet
		210 feet

Below this section, in the same locality, are several thick layers of red sandstone.

We continued three miles to the east prong of Fossil creek. The Plains are only a mile away, and the escarpment turns abruptly to the south.

The following section was made at the head of one of the small tributaries of East Fossil creek:

SECTION 19.

1.	Brown limestone	40 feet.
2.	Pinkish colored sand with calcareous nodules	60 feet.
3.	Yellow calcareous sandstone	150 feet.
4.	Blue shale, fossiliferous	60 feet.
5.	Yellow fine-grained sandstone	240 feet.
6.	Red clay, with seams of sandstone	250 feet.
		800 feet.

No. 1 of this section is a brownish unevenly textured arenaceous limestone. Bands of darker and lighter shades run irregularly through

it, and pieces of opalized silica often occur in lumps or irregular thin sheets, and the whole mass shows a general appearance of segregation of the different material. The rock has no well defined plans of stratification, but is a mass of concretions, seams and irregular surfaces. The top, however, is a little more uniform in texture, and in this part the opalized material occurs.

No. 2 is a mass of pink colored sand, containing nodules of calcareous sand, often red, but generally white, especially when close to the top, and containing considerable lime. The sand is a mixture of fine and coarse grains, mostly white, but with some red grains.

No. 3 is a yellow calcareous sandstone, often pure sandstone, but at the base and top generally highly calcareous. At some places near the top the stratum contains thin layers of iron ore. Siliceous water-worn pebbles occur sparsely in layers at some places. Towards the base the sand is rather fine, but near and at the top it is coarse and bound by a lime matrix into a firm hard rock that is often false-bedded, the planes of this bedding dipping to the south southeast. The rock throughout the bed is generally massive. The top is in places a white quartzitic-like sandstone.

No. 4 is a blue shale, containing in places thin bands of sandy clay and some fossiliferous calcareous nodules. The lower half or more of this bed is the *Gryphæa tucumcari* horizon. At the base is a stratum of water-worn siliceous pebbles, one foot thick in places.

No. 5 is principally a fine grained yellow sandstone, often having through it black specks and dendrites. At places it is white, and varies in thickness from massive layers of fifteen feet to thin ripple marked layers of only a few inches. Some bands of red and arenaceous blue clay are interstratified with the sandstone.

No. 6, where exposed at this place, is principally a more or less arenaceous red clay, slightly shaly in places. Thin bands of blue, greenish and purple clays also occur in layers of sandstone from one inch to three feet in thickness. The sandstones are generally white or bluish, but some of the thin layers are red, or red with blue spots.

Nos. 1 and 2 of the above section belong to the Blanco beds. From 3 to 5 inclusive are the Tucumcari beds. No. 6 is the Triassic. The Blanco beds are not different from what has been seen elsewhere, except as to the color of No. 2, which is merely local, that bed generally being white. The Tucumcari beds are different from anything seen elsewhere except in this vicinity. The Triassic is about the same as the upper parts of the beds in other localities.

The following section was made at the point of the Plains where the escarpment turns abruptly to the south for some distance:

SECTION 20.

1.	Limestone	34 feet.	
2.	Massive sandstone	80 feet.	
3.	Bluish shale	85 feet.	
4.	Conglomerate	1 foot.	
5.	Blue clay	4 feet.	
6.	Red clay	10 feet.	
7.	Massive yellow sandstone	50 feet.	
8.	Sandstone		4 inches.
9.	Purple clay, with petrified wood	15 feet.	
10.	Gray sandstone	8 feet.	
11.	Red sandstone	1 foot	6 inches.
12.	Red clay	2 feet.	
13.	Bluish sandstone	1 foot	6 inches.
14.	Blue sandstone		4 inches.
15.	Red argillaceous sandstone		3 inches.
16.	Red clay	12 feet.	
17.	Heavy blue sandstone	1 foot	6 inches.
18.	Gray, fine grained sandstone, cross-bedded	1 foot.	
19.	Blue clay	3 feet.	
		310 feet	5 inches.

At this place the Tucumcari dip at a much greater angle to the southeast than do the Blanco beds, and only the upper limestone is found resting directly upon the Tucumcari beds. This is merely local, as I found by following up one of the canyons a mile, where I found the fault in the strata of the Tucumcari beds, which there resumed their usual inclination, the other Blanco beds being in contact with the tilted sides of the Tucumcari.

The sides of the mountains here are covered with a heavy growth of cedar and pinyon pine. There are no springs in the heads of the canyons here, as in those further east.

Half a mile below this section, on Fossil creek, are heavy beds of cross-bedded sandstone, with scales of mica.

We continued westward along the old trail to a creek (marked Fossil creek on the map) flowing into the Canadian river. Water is standing in holes along the bed, and we got good water by digging pits in the sand. Groves of cottonwood trees are found along the creek. The country traveled over is quite level with no exposures of the strata.

Continuing along the old trail for four miles, we turned almost directly north in the direction of Little and Big Tucumcari mountains, the point of divergence being about opposite Mount Rivuelto, a high mountain on the south of the old trail. This mountain was by mistake called Big Tucumcari on the map published by Marcou.

At this mountain are seen two steppes, the lower composed of the Triassic and the upper of the Tucumcari and Blanco beds. The Tri-

assic steppe is about as high as the top of the Staked Plains, and I think this is why Marcou thought its lower strata was the same as that where they crossed the Plains. We passed by the base of Little Tucumcari mountain on the east side, crossing at that place Tucumcari creek. In the bed of the creek is the cross-bedded micaceous sandstone of the Triassic.

A few miles further we passed the base of Big Tucumcari mountain, on the western side, and camped at the base on the north side, which is almost a perpendicular precipice, with all the strata well exposed.

The following section was made of the mountain :

SECTION 21.

1.	White limestone	20 feet.
2.	Massive sandstone	60 feet.
3.	Black shale	50 feet.
4.	Massive yellow sandstone	235 feet.
5.	Red sandstone	30 feet.
6.	Blue clay	4 feet.
7.	Purple clay	6 feet.
8.	Arenaceous clay	1 foot.
9.	Blue clay	4 feet.
10.	Purple clay	16 feet.
11.	Light red clay	30 feet.
12.	Dark red clay	145 feet.
		601 feet.

We continued north about five miles to Liberty, on the west side of Pajarito creek, and there turned south along the road to Fort Sumner, which is said to be seventy-five miles distant.

At several places we passed near the foot of high hills having about the same section as Tucumcari. We made camp at a pool of water at the base of a hill showing the same strata, about twelve miles south of Liberty, on the north edge of Plaza Larga, an immense level plain lying at the base of the high hills. There is very little timber of any kind on our route except cedar on the sides of the mountains, and cottonwood and hackberry along the creek.

We continue southward about ten miles, and having crossed the old Government trail, came to a hill on the west, a few miles east of Pyramid Mount, where the following section was made:

SECTION 22.

1.	White limestone	40 feet.
2.	Sandstone, top in layers	80 feet.
3.	Bluish shale	25 feet.
4.	Massive yellow sandstone	40 feet.
5.	Red clay	140 feet.
6.	White sandstone	10 feet.
7.	Red clay	20 feet.

8.	Brown sandstone	5 feet.
9.	Red clay	22 feet.
10.	Red sandstone	5 feet.
11.	Red clay	3 feet.
12.	Blue clay	5 feet.
13.	Purple clay	10 feet.
14.	Red clay	173 feet.
15.	Conglomerate	10 feet.
16.	Red clay	10 feet.
17.	Red sandstone	4 feet.
18.	Conglomerate	8 feet.
19.	Bluish sandstone	1 foot.
		603 feet.

At the southern foot of this mountain is the head of the creek which runs at the base of Little Tucumcari mountain.

At the foot of the mountain, lower than any part of the above section, was a Triassic sandstone full of mica scales, about the same that we had seen everywhere in that formation. This hill contains the most southern extension of the Tucumcari beds.

The top of this mountain is about one hundred and fifty feet higher than the top of the Staked Plains, which begin about four miles to the south.

We traveled southwestward, and at four miles ascended again to the top of the Staked Plains, which are here four hundred and twenty feet above the creek at the base of the last mountain. The escarpment here is very abrupt and difficult of ascent. The strata of the Plains is composed of the Triassic and Tertiary, the Tucumcari beds having entirely disappeared. The same white limestone is at the top of the Plains here as was found elsewhere and on the top of the hill at which the last section was made. Where we ascended there is a sand-hill for a mile or two in extent covered with "shinoak" brush.

After traveling two miles, we descended into a basin, two miles wide and three miles long, about one hundred feet below the level of the surrounding plain, in which were two salt lakes. At the northwest side there is a bold spring of fresh water. After leaving the basin we traveled over the high level plateau, in a southwestern course, crossing the head of one canyon, and at distance of fourteen miles again went down off the Staked Plains, where the top of the escarpment was two hundred and fifty feet above the level of the valley below. The strata comprised the Blanco beds resting directly upon the sandstone of the Triassic.

We continued to descend by a gradual slope for a few miles to a creek where we found the sandstone of the Triassic in which the large scales of mica occur, and camped near the residence of Fred Garret, formerly a resident of Texas, getting water from his well, the only

water to be had in the vicinity, and wood from his woodpile, as there is no wood in the country except in the cedar brakes several miles away. We have been traveling southwest almost parallel with the escarpment of the Plains, which is here only a mile or two away. From this place it is fourteen miles to the Pecos river, which we reach three miles above old Fort Sumner.

The route traveled was over a succession of hills that are nothing more than sand dunes, varying in height from ten to fifty feet, overgrown with scrub oak. So deep was this drift sand it was impossible to get a section of the strata over which we were traveling.

The channel of the river, where we reached it, was about three hundred yards wide, and at the time was entirely covered with water, there being a heavy rise in the river from recent rains. Although the bed of the river is so wide, the depth of the water was not over three feet at the deepest place, and was very muddy, but the mud soon settled when dipped out and allowed to stand for a few moments.

We attempted, as usual, to get clear water by digging shallow pits near the margin of the stream, but found the soil so highly impregnated with salts that the water, in percolating through, became more highly charged than it was in the river.

We continued down the river to old Fort Sumner, a distance of two miles. The fort was abandoned by the troops in 1870, since which time the place has been in a very dilapidated condition. At the time of its occupancy by the troops a dam was built across the river a few miles above, and the water taken out to irrigate the valley. Long lines of cottonwood trees mark the place of the old canal, and the groves show where the land was irrigated. Soon after the soldiers abandoned the fort the dam was washed out and has never been rebuilt, probably for lack of demand for agricultural products, and of capital.

Crossing the river at the old fort we took the road to Roswell, and twelve miles distant reached Coyote creek, where I made the following section:

SECTION 23.

1.	Quaternary conglomerate	6 feet.
2.	Clay ironstone conglomerate	4 feet.
3.	Dark brown clay	6 feet.
4.	Dark red laminated sandstone, with insect tracks	2 feet.
5.	Dark brown clay	4 feet.
6.	Sandstone, micaceous	8 feet.
		30 feet.

These strata all belong to the Triassic, except the upper conglomerate. The water in the creek was fresh.

We again reached the river at twenty miles from Fort Sumner. The valley is covered with an incrustation of salt. On the east side of the river, opposite the camp, and at the edge of the water, is a bed of mas-

sive gypsum. The beds of Triassic clays and sandstones rest directly on the gypsum. One mile southwest, in the head of a ravine, is a spring of fresh water and a small irrigated farm.

We continued down the river for twenty miles, and camped near an irrigation ditch. The dam had been built out of logs hauled out of the mountains, but so insecurely built that the first heavy rise in the river washed it out. It is perfectly useless to try to dam the Pecos river in any such way. The owner of the ditch has abandoned the idea of irrigating his land by damming the river, but will cut the head of his ditch two feet lower, which will put it on a level with low water, and the water can be put on the land at the same place as before. During the day we passed over beds of massive gypsum, red clay, and red and white sandstones. In the afternoon we saw beds of magnesian limestone of the Permian.

The western escarpment of the Staked Plains was plainly visible from the tops of the hills at a distance of about ten miles. With a field glass we could distinguish the white bluffs of the upper beds from the underlying red beds.

We continued down the valley of the river for three miles, passing several farms that were to have been irrigated by the water from the ditch just mentioned. The corn in the valleys would make a partial crop, and the wheat and oats had made fair crops, having been irrigated well up to the time of the washing out of the dam.

Leaving the river we traveled over the ridge composed of gypsum and red clay beds. At noon we halted at Twenty-five Mile creek. The water is highly charged with salts, and is the worst we have had to use on the trip. It comes from beneath the Quaternary conglomerate, which rests on red clay interstratified with gypsum.

In the afternoon we passed over a succession of hills and valleys. At one place we crossed an alkali flat of a mile or more in extent, on which there was not a vestige of grass or any other vegetation.

We camped at night on Salt creek, at a large spring of fresh water. The spring is at the base of a stratum of white chalky limestone, resembling the upper beds of the Staked Plains, and which we take to be the same. Salt creek is a bold running stream, the water in which is quite bitter. The only grass we have had for the last two days for our teams was the salt grass of the rivers and creeks.

From Salt creek we passed on to a broad level plateau that extends many miles southward, and reaches the foot hills of the mountains on the west. We suppose this broad plateau to be the same as the upper beds of the Staked Plains. It was generally covered by soil so that no section could be made. We saw no gypsum in beds or otherwise, but in all the shallow gulches the same white limestone we had seen at Salt creek.

Three miles north of Roswell we came to a stream of clear water

that has its source only a few miles to the westward. The water from this creek has been taken out by canals on both sides of it and used for irrigating the valley below.

At the town of Roswell, on the north side, we crossed North Spring creek, a bold running stream thirty feet wide and two feet deep. The water was only slightly impregnated with common salt. Two large irrigating ditches connect with this stream above the town.

South of the town is the Hondo creek, which has its source in the mountains to the westward. All the water has been taken out of the channel by ditches, but only a part of it has been used, the balance going back into the original channel below the town.

From Roswell we took the road to Eddy, almost directly southeast. In going up to the top of the Plains from the Hondo, we saw in a small bluff the white chalky limestone of the upper beds. South of Roswell is an immense level plain extending as far as the eye can reach. This immense plain can all be reached by water from the irrigating canal.

Five miles from Roswell is South Spring creek. This is one of the largest springs in the Territory. The water has only been partly used for irrigation. It is now taken out by three canals. North Spring creek flows into the Hondo. Below the junction the Pecos Irrigation and Improvement Company have built their northern irrigation canal, which takes up also the water of South Spring creek. This canal, when completed, will be fifty miles long, thirty feet wide at the bottom, with a fall of one foot to the mile, and will carry a depth of five feet of water.

We continued on the level plateau, and passed several new settlements preparing to use the water from this canal. The settlers were digging wells for domestic purposes, water being obtained in great abundance at a depth of thirty feet. The material passed through in digging these wells was soft and chalky, and at other places a hard, white limestone, resembling the upper beds of the Staked Plains, and no doubt identical with them.

Twelve miles from South Spring is a well at the stage stand forty feet deep. The only material passed through in digging this well was a reddish sandy clay, resembling the lower part of the Blanco beds, and probably the same. The water in these wells is entirely free from salts, at least they could not be detected by taste.

We made camp on the Felix creek. This stream has its source in the mountains to the west. At some time it has cut down through the limestone, but the valley has again been filled up with the drift material from the mountains.

In a well dug in the valley water was found at a depth of twenty feet. It was dug all the way through the drift of sand and limestone pebbles to the clay. In some of the pebbles I found carboniferous fossils.

A few miles north of the canal, and on the opposite side of the river, are hills of red clay and sandstone.

Far away to the eastward, probably twenty-five miles, can be seen the high escarpment of the Staked Plains extending apparently parallel with the river in an unbroken range. At that place it presents a white, bold, precipitous face, much the same as seen along the eastern escarpment.

The soil we have been passing over since leaving Roswell is free from any efflorescence of salt, being in this respect different from the soils along the Pecos river north of that town.

We continued along the Eddy road over a broad prairie, with an occasional patch of Quaternary drift composed of Carboniferous limestone pebbles At ten miles we passed Tarr lake, a small body of water fed by springs. The water was quite salty. At eleven miles we passed the stage stand, where we got fresh water from a well twenty feet deep. At eighteen miles we turned eastward from the Eddy road three miles to a spring of fresh water. The country is more broken than yesterday, but is all covered with Quaternary drift, so that the underlying beds could not be seen. No kind of wood, except here and there a patch of mesquite, where the roots may be dug for wood.

After leaving camp we passed within the distance of three miles two nice bold springs in the head of ravines. The water is almost entirely free from salts. At a distance of five miles we again reach the Eddy road, and a mile further reach the Penasco river at Gilbert's ranch. The water has nearly all been taken out of this river by irrigation ditches, one on each side. It has its source in the mountain range to the west, and the water is free from salts. Gilbert has a bois d'arc hedge around his place that seems to grow very luxuriantly, too much so in fact to make a good hedge.

At one mile south of Gilbert's we passed another spring of water. There was no exposure of the strata, it all being covered with Quaternary drift from the mountains. We could see the red hills in the distance on the east side of the Pecos river.

At seven miles from Gilbert's we reached Cook's farm. This farm is irrigated with water taken out of Seven rivers. The water is free from salts, and the farm is devoted to raising alfalfa and Johnson grass. We camped at night at Seven Rivers, having traveled about twenty miles.

At Seven Rivers the Pecos runs against a bluff of limestone that very much resembles the magnesian limestone of the Permian, but we could find no fossils in any of the beds.

A spur of the Guadalupe mountains comes to the Pecos at this point. The beds are white or slightly yellowish even textured limestone. They are probably Permian, but after diligent search we could find no fossils. These beds extend to Eddy, and at that place under-

Fig. 7.

Section from Eddy, northeast and east to the top of the Staked Plains. E. Eddy. P. Pecos river. C. Clayton Wells. S. Salt lake. R. Estes ranch.

1. Quartenary (?) conglomerate. 2. Permian. 3. Dockum beds, Triassic. 4. Blanco beds, Tertiary. Vertical scale, one inch to one thousand feet. Horizontal scale, one inch to six miles.

lie the town and extend across the Pecos river, on the east bank of which is a bed of conglomerate seventy-five feet thick, composed of boulders from the limestone strata west of the river, and siliceous pebbles. The matrix is rather coarse and calcareous. Five feet of the brownish banded segregated limestone lies on top of this conglomerate.

1. Conglomerate of large limestone pebbles, some of which are one to two feet in diameter, with a few small siliceous pebbles scattered through it. The matrix is coarse sand and calcareous material. On top of the hill above this conglomerate is four or five feet of highly calcareous strata which very much resemble the top strata of the Tertiary further east.

2. Gypsum beds as Permian. This is a massive bed of gypsum, the lower part gypseous clays, and the top gypseous clays and white limestone.

3. Dockum beds of sandy clays, clayey sands and sandstone.

4. Tertiary strata of the Staked Plains.

5. A bed of white hardened sandy clay or clayey sand of Recent formation and small extent.

From Eddy northeast, twenty miles, to the Clayton Wells, and then east to the Estes ranch on top of the Plains, there are but two formations, constituting most of the outcropping strata. From Eddy to the Clayton Wells is nearly all Permian, and from the Clayton Wells to Estes ranch is nearly all Tertiary.

On the east side of the well opposite Eddy there is about seventy-five feet of Quaternary conglomerate, the pebbles of limestone rock so much like the rock of the limestone strata west of town

as to leave but little doubt that it was derived from that strata. This conglomerate forms isolated beds up and down the river, or lies in narrow belts along the bank in places, the same as along Black river near Lookout.

The limestone which outcrops west of Eddy extends across the river northeast of town, and forms a belt one or two miles wide on that side of the river. This belt extends with some breaks as far north as Seven Rivers. Six miles above Eddy, at the dam, this limestone forms a bed on both banks of the river.

Northeast of the dam, and in places to the east, the surface is covered with a belt of deep sand that extends north and south and hides nearly all the strata from view.

East of the narrow belt of conglomerate are limestone and sand beds which extend along the river to the west of the escarpment of the springs at the Clayton Wells, at a distance of twelve or fourteen miles. The outcropping strata are parts of the massive gypsum beds of the Permian. This gypsum belt extends far up and down the river with varying width, and at places extends across and spreads out to a considerable extent on either side, as between Eddy and Lookout. This formation northeast of Eddy produces a slightly rolling surface with here and there small basins or depressions.

Small caverns extend deep into the gypsum bed in many of these basins, and the drainage is mostly underground to these caverns. Sometimes no caverns can be seen, but a small depression covered with sand in the lower part, shows the outlet of the drainage for that basin. This massive gypsum bed is probably over one hundred feet thick, and contains some carbonate of lime and some earthy material. Planes of dark color are quite regularly distributed through it. All the outcrops are more or less disintegrated, and the ground is often covered with pulverized or disintegrated gypsum to such an extent that it looks a little like dirt mixed with powdered chalk spread over the ground. A well section just east of Eddy showed this massive gypsum bed to be overlaid by gypsiferous clay containing considerable salt.

Indications are also that a thin bed of sandy gypsiferous clay sometimes lies between the massive gypsum bed and the overlying white limestone.

Just south of the mouth of Black river, thirty or forty feet of sandy gypsiferous clay can be seen underlying the white limestone, and the base of the clay is not exposed.

The low parts or swags in the gypsum beds often show a remarkable sub-irrigation by the growth of grass, weeds and mesquite bushes. In one of these swags, about five miles northeast of Eddy, an abundance of gypseous water is obtained at a depth of seven and eight feet, and corn, cane, pumpkins, etc., grow well without artificial irrigation. At

the Clayton Wells water is gotten at a depth of about twenty-five feet in such quantities that the wells have never been pumped dry.

Twenty five miles further east, at the Estes ranch, in a swag on the top of the Plains, water in abundance is reached at a depth of fifteen and sixteen feet. The escarpment just east of Clayton Wells extends approximately north and south, and its basal part consists of forty or fifty feet of red clayey sands of the Dockum beds.

Above the Dockum beds there is about one hundred feet of Tertiary sand capped with a few feet of hardened calcareous clay. Between this escarpment and the escarpment of the Plains proper, a distance of about twenty miles, nearly all the country is covered with deep loose sand and a growth of small "shinoaks." There is, however, a narrow belt, five or six miles long, extending east and west on either side of the Salt lake, that has only a little drift sand, the ground being quite firm and underlaid by a hard white clayey sand, which probably is a continuation of the Recent bed (5) found at Salt lake, though it may be Tertiary material. The bottom and lower parts and the west and south side of Salt lake are Dockum beds, sandstone and sandy clay.

On the north side of the lake, about twenty feet above the bottom, is five or six feet of white hardened sandy clay that contains a great many Recent land shells, such as *Pupa*, *Helix*, *Succinea*, and *Zonites*, among the terrestrials, and *Sphærilum* of the fluviatiles.

The top of the Plains at the Estes ranch slopes gently down to the undulating country to the west, but the escarpment, whether general or abrupt, is but about fifty feet, and at the top twenty-five or thirty feet of this is the hardened clay and limestone. At the base of this is some of the pinkish brittle quartzitic sandstone, which has segregations of clear and milky siliceous particles as also has the top limestone or clay. In the sands about one and a half miles west of the above escarpment a well section shows a great many siliceous pebbles in some of the lower horizons of the Tertiary strata.

We went south from Eddy to Lookout, near the mouth of Black river, a distance of fifteen miles. After the first six miles the way is mostly over disintegrated gypsum. Three miles north of Black river is a ridge thirty feet above the surrounding land, the top of which is a breccite limestone, the matrix and angular pieces of stone nearly the same material in color and texture, both resembling the limestone seen north of Eddy.

On the west bank of the Pecos, about three miles below the mouth of Black river, are layers of yellowish, evenly textured, smooth limestone, fractured and full of seams, with gypsum and red clay below.

A Quaternary conglomerate about thirty feet thick, of limestone boulders and siliceous pebbles, with a matrix of lime and sand, lies in Black river basin, through which the river for about four miles up from the mouth has cut its channel. A number of good springs flow

from its base into the river. At Lookout this conglomerate extends two miles north of Black river, and it is found in the bed of the Pecos at the mouth of Black river forming a rough bottom for half a mile. Just east the conglomerate rises to the height of seventy feet above the river bed, and is capped by a limestone five or six feet thick, containing an occasional siliceous pebble and some sand, and resembling in lithological characters that often seen capping the strata of the Staked Plains.

We traveled up Black river on the north side, and three miles west of Lookout found heavy bedded limestone on both sides. The limestone is the same that occurs at the mouth of Delaware creek, and is no doubt Permian, yet no fossils were found in it. This bed of limestone was thought to be Cretaceous by Dr. Shumard, but he found no fossils, and placed it in the Cretaceous for stratigraphic reasons. It will be remembered that he put all the red beds, both of the eastern and western side of the Staked Plains, in the Cretaceous, under the name of Marly Clays. He found this limestone above the red clays, and very naturally concluded, in the absence of fossils, that it was Cretaceous.

We continued up the river, passing Blue springs, the water from which is free from salts, and is used for irrigating the lands in this vicinity. There is a spur of the Guadalupe mountains on the northwest of our route running almost parallel with the course of the river. We are unable to see any part of the strata except the Quaternary conglomerate. The high ridge of gypsum can be seen a few miles to the south. We camped at the head of Black river at night.

Near the head of the river the beds of massive gypsum are on the south side. The head spring of the river is in a broad valley of erosion between the gypsum beds and the Guadalupe mountains, entirely covered with Quaternary drift, and at this place about six miles wide. The water in the river, which evidently comes from the Quaternary drift, is only slightly impregnated with gypsum, and is used for irrigating the valleys below.

We continued up the valley of erosion between the mountains on the west and the gypsum beds on the east, in about a due southwest course. In about ten miles we reached Grapevine springs at the headquarters of the U. S. ranch. The water is pleasant to the taste, but highly charged with carbonate of lime, and is partly used to irrigate a small farm planted in corn and Johnson grass. In the vicinity of the spring and below are heavy beds of calcareous tufa.

Finding it impossible to get through the country with the wagons any further in that direction, we turned eastward a few miles and reached a road leading from the head of Black river to Delaware springs. At three miles we left the Quaternary drift, which is here composed of very large bowlders from the mountain, and entered upon the Permian, the

beds of which at this place are about two hundred feet thick, and the gypsum beds are very cavernous. Cedar trees grow in places along the bluff. We camped in the valley without water, and with very poor grass.

Upon reaching the road we turned almost directly south, and for about eight miles were on the gypsum beds; then, going down a steep hill, we found the sandstones of the Carboniferous in the valley, and three miles further reached Delaware springs, which was once a stage station on the overland mail route from California. There are several springs at this place, one of which, issuing from the Carboniferous strata, is highly impregnated with various saline matters, imparting a very disagreeable taste, and emitting the odor of sulphureted hydrogen, which can be detected for some distance. The water that comes from the Quaternary drift, which here fills the valley, is pure and palatable.

There have been heavy denudations of the strata in this vicinity, the hills being about two hundred and fifty feet high.

The following section was made at a hill near the head of Delaware creek, on the north side of the valley:

SECTION 24.

1.	Heavy bedded limestone	50 feet.
2.	Thin bedded limestone	100 feet.
3.	Quartzose sandstone	20 feet.
4.	Dark limestone, thin bedded	3 feet.
5.	Sandstone, fine grained	7 feet.
6.	Sandstone and limestone, interbedded	70 feet.
		250 feet.

The shaly thin bedded limestone in the bed of the creek, just above the upper spring, has very straight lines of fracture running across it in three directions. The drift sand is very deep in the vicinity of the springs, and covered with mesquite brush.

We went down the Delaware on the north side for three miles, and then crossed to the south, following the road leading to Pecos City. Immediately after crossing the creek we came to the gypsum beds, which we ascended by several steppes for about one hundred and fifty feet. They are mostly decomposed white gypsum, with seams of carbonate of lime. Ten miles further we camped at Castile springs, which issue from the massive gypsum at the head of a deep canyon which extends to the Delaware six miles north. The water is heavily charged with gypsum, the pool at the spring being a deep green color, and quite bitter. We had been informed that there was a bed of native sulphur in this vicinity, but after a diligent search for it for two days were unable to find it.

Four miles south of our camp is a deep canyon cut down into the massive gypsum. There are a few cedar trees growing on this canyon as well as at other places near.

We moved our camp about five miles northeastward along the road to a spring of gypseous water. On the top of some of the highest hills we have seen fragments of limestone that very much resemble the Permian limestone east of the Plains, but have not found the beds from which the fragments come. There were no fossils in them.

We continued along the Pecos City road, passing through a gap between a range of hills about a hundred and fifty feet high, capped with magnesian limestone which is no doubt Permian, though we could find no fossils after a most diligent search. The range of hills running from northeast to southwest are probably the same beds seen at the mouth of Delaware creek.

Six miles further we reached Screw-bean springs, a bold running stream of gypseous water which flows into the Pecos river. At this place we reached the road from Eddy to Pecos City. From this place the road is a straight line.

This is the last permanent water on the road until we get near Pecos City, but at fifteen miles we were fortunate enough to find a pool of water made by recent rains, otherwise we should have had to make the whole distance, forty miles, without water for our stock.

From Screw-bean spring to Pecos City the country is covered with Quaternary drift, so that nothing else was seen. Formerly when all the traffic for eastern New Mexico passed over this road, the citizens of Pecos City had wells dug at convenient distances to supply the freighters, but since the building of the railroad from Pecos City to Eddy this road has been less used, and the wells have not been kept up. There are no settlements of any kind on the road from Screw-bean to Pecos City, not even stock ranches. The grass in places is good, but there is no water for any purpose.

We crossed to the east side of the Pecos river at Pecos City, and camped about fourteen miles below, where we found Permian beds of red clay and gypsum, with the bed of Quaternary drift on top of the red clay. This camp is about south of Quito station.

Continuing down the river, at about three miles, we come to the massive beds of red sandstone that is being so extensively quarried west of Quito. I think this sandstone is Triassic. It is underlaid by red clay with selenite.

We continued down the river to the falls. The valley on the east side is about one mile wide and widens to three or more on the south, and then closes in again at the falls to one half mile. The escarpment on the east is not more than thirty feet high, and is always capped by the white conglomeritic limestone so characteristic of the Blanco beds. This rock here contains sand, siliceous pebbles, and pieces of red sandstone, and is from three to five feet thick.

There are two falls in the river at this place in a distance of about one hundred yards. The upper fall is about three and a half feet and

the lower about five and a half feet. The stone making the falls is a coarse conglomerate composed of carboniferous, porphyritic and siliceous rocks with a light sand matrix slightly ferruginous.

We continued down the river thirty-eight miles to Horsehead Crossing, traveling along on the flat valley of the river. The low escarpment facing the valley was red marly gypseous clay overlaid unconformably by ten feet of red slightly argillaceous sand, and this was overlaid by ten feet of the white conglomeritic limestone so characteristic of the upper beds of the Staked Plains.

We here left the river and took the road to Castle Gap, camping ten miles further on, and seven miles beyond passed through Castle Gap. The strata seen between Castle Gap and the Pecos river was the upper limestone of the Staked Plains and the deep sand beds that had formed above it. The following is a section of Castle mountain:

SECTION 25.

1.	Limestone, hard	6 feet.
2.	Clay and limestone	15 feet.
3.	Limestone	20 feet.
4.	Limestone	30 feet.
5.	Clay, yellowish	12 feet.
6.	Limestone	60 feet.
7.	Clay, yellowish white	20 feet.
8.	Limestone, rotten	5 feet.
9.	Limestone	80 feet.
10.	Sand, compact	50 feet.
11.	Calcareous sandstone	90 feet.
12.	Conglomeritic sandstone	30 feet.
		418 feet.

No. 1 of this section is firm, evenly weathering white limestone, that would make very good building stone. The layers are about two to three feet thick.

No 2 is alternating clay and argillaceous limestone layers, containing a large number of *Diadema*, *Toxaster texanus*, *Pecten texanus*, some *Arca*, several species of gasteropods and a small *Gryphœa pitcheri*.

No. 3 is a white crumbling limestone, forming a prominent horizon that stands out beyond the rock below and above, as it resists the atmospheric influences better than they.

No. 4 is a crumbling white argillaceous limestone, somewhat similar to the one above.

No. 5 is a clay containing a great number of *Gryphœa pitcheri* and a few *Exogyra texana*.

No. 6. White crumbling limestone containing a few fossils.

No. 7 is an argillaceous bed containing *Arcopagia*, *Lima wacoensis*, *Toxaster texanus*, *Arca*, *Ammonites*, *Diadema*, *Pecten texana*.

No. 8 is a slightly ferruginous limestone containing many small *Gryphœa pitcheri*.

No. 9 is a nearly uniform friable white limestone, though it has some layers of marly material that weathers more rapidly. The most common fossils are *Arca*, *Toxaster texanus*, *Diadema*, *Pecten* and small *Gryphæa pitcheri*.

No. 10 is a white compact sand containing a few siliceous pebbles and calcareous pink sandstone near the top, which is slightly fossiliferous. This strata shows a graduation into the one below.

No. 11 is a massive calcareous sandstone. It has much white sand, but the weathered surface of the rock is always brown. The rock varies in its proportion of lime, but this never becomes the principal ingredient of the stone, except in streaks. False-bedding occurs in places, and a few siliceous pebbles are found in the bed at some of the localities. The stone is generally firm and weathers into large bowlders, yet there are one or two layers of friable stone in the middle of the bed.

No. 12 is a red friable conglomeritic sandstone, very much resembling the characteristic Triassic bed at Dockum. Hardened small pieces of calcareous clay and sand, of yellowish and brown colors, and pieces of red sandstone and calcite make up the mass of rock. At the center and top of this stratum, as seen here, the rock is a shaly micaceous red sandstone and red marly clay.

We continued along the old Centralia road about twenty miles. The Castle mountains escarpment that faced the north and ran nearly parallel with our route yesterday now turns to the southeast. About ten miles of the road traveled to-day was rolling or gently sloping plains. The outcropping was the lower part of the Cretaceous limestone.

We traveled to Centralia and camped five miles east of it on the San Angelo road, going down off the upper plains into a water drainage canyon, and in passing down crossed over the Caprina limestone.

At Centralia station and elsewhere along the canyon there is about fifty feet of the Caprina horizon shown in the escarpment facing the valley. About forty feet of this bed is well exposed, and consists of several layers of firm, evenly textured white limestone from one to two feet thick, with thinner intervening layers. A great many of these layers have an oolitic appearance. Nearly all of them would make excellent building material. Three of the thickest—one near the top, one in the middle, and one at the bottom of the section—contain a great number of the Caprina and Caprotina fossils as well as some other forms; also a great many flint nodules which are usually fossiliferous, porous and slightly calcareous. The barometric height of the Caprina limestone at this place is two thousand five hundred and twenty feet.

There are numbers of wells in this valley of excellent water, ranging in depth from twenty-five to one hundred and twenty-five feet.

We continued along the same valley twelve miles and reached the middle fork of the Concho river; then down the river twelve miles and

camped on the north side. Charlotte postoffice is about one mile west of camp. At that place the following section of the strata was made:

SECTION 26.

1.	Caprina limestone	10 feet.
2.	Massive limestone	32 feet.
3.	Massive arenaceous limestone	38 feet.
4.	Yellow stratified sand	40 feet.
5.	Deep red vermilion clay	3 feet.
		123 feet.

No. 1 of this section is generally a white, evenly textured, firm limestone, in layers from one inch to two feet thick, containing layers of flint nodules and Caprina and Caprotina fossils. This is the lower part of the bed seen at Centralia.

No. 2 is a massive bed of limestone in layers, some of which weather into a honey comb structure or surface. A large part of it is a white argillaceous stone that readily crumbles into angular pieces, and it also has flint nodules and Caprotina fossils in several of the layers.

No. 3 is a massive arenaceous brownish limestone that weathers rather easily. Some of the layers are harder than others, making projecting and receding rounded layers of scalloped profile.

No. 4 is a compact, iron stained, yellow, stratified sand, some of the layers ten feet thick. At the top is eight feet of arenaceous yellow clay and shaly sandstone. One inch layer near the center has a great many siliceous pebbles. One thin bed of red clay also occurs near the center.

No. 5 is a deep vermilion red, marly clay, slightly arenaceous. The base of the bed was not seen.

About fifteen miles down the river we came to the Quaternary conglomerate, and continuing on, camped one mile from San Angelo, at which place our work ended.

Having given thus in detail the constitution and variations of the several beds observed in this trip around the Plains, it may be well to review briefly the character and extent of the different formations whose presence was determined.

QUATERNARY.

At many places on top of the Staked Plains occur beds of sand, gravel and bowlders, much water-worn, that I have referred to the Quaternary. On the higher plateaus and in the valleys of the rivers east of the Staked Plains the same character of material occurs. I have also seen it east of the Wichita mountains in the Indian Territory. East of the Staked Plains this drift is mixed with material from the Triassic, but so distinctive is the character of the bowlders, they are easily recognized wherever seen.

This Quaternary is different from the later deposits of that period found along all the creeks and rivers on both the eastern and western sides of the Staked Plains. In the later there are a great many fossils, both vertebrate and invertebrate, but in the earlier none have been found except fragments of silicified wood, and that only from the beds east of the Staked Plains.

The later beds along the Big Wichita river are often one hundred and fifty feet below the earlier deposits, and these later beds are often one hundred feet above the present channel of the Big Wichita and Brazos rivers.

West of the Staked Plains the later Quaternary conglomerate is in the beds of the rivers and creeks and one still later is spread out over large areas as if there had been an interior lake basin with its deepest side on the east next to the Plains.

TERTIARY.

In both the First and Second Annual Reports of this Survey the beds which I have described under the name of Blanco Canyon beds have been correlated with the Tertiary.

The only fossils collected from these beds were vertebrate. They were sent to Professor E. D. Cope, of Philadelphia, Pa., who in a private letter writes that the beds are Pliocene and probably belong between the Equus and Loup Fork beds. A paper on these fossils by Professor Cope will be found elsewhere in this Report.

Besides having traveled entirely around the Staked Plains, I explored several of the deep canyons extending back into the high plateau, and everywhere north of the Texas and Pacific Railroad the upper strata belong to the Blanco beds, except a narrow border along the eastern side, patches of Quaternary drift, recent soils, sand dunes, and a few small areas of Cretaceous.

The following are some of the sections made of the Blanco beds at various localities; the numbers are the same as those used on the map:

SECTION 13.

At the foot of the Staked Plains, three miles north of Dockum:

1.	White sandy clay	6 feet.
2.	White diatomaceous earth	3 feet.
3	Purple clay	3 feet.
4.	White diatomaceous earth	4 feet.
5.	Reddish sandy clay	150 feet.
		166 feet.

In the beds Nos. 2 and 4 of the above section there are many diatoms. The material is very light and soft, like chalk. In No. 1 occurs a fossil land tortoise recently described by Professor Cope.

MT. BLANCO.

SECTION 12.

One mile south of Mount Blanco, Crosby county:

1.	Soil	8 feet.
2.	Limestone	2 feet.
3.	Sandstone	3 feet.
4.	Limestone, stalactitic	4 feet.
5.	White calcareous sandstone	4 feet.
6.	White sandy clay	30 feet.
7.	White diatomaceous earth	4 feet.
8.	Pack sand	20 feet.
9.	White diatomaceous earth	8 feet.
10.	Greenish sandy clay	30 feet.
11.	Red clay	2 feet.
12.	Reddish clay	30 feet.
		145 feet.

SECTION 13.

One-half mile west of Mount Blanco postoffice, and one and a half miles north of the preceding section:

1.	Limestone	2 feet.
2.	Stalactitic limestone	10 feet.
3.	Red clay (same as No. 12, preceding section)	130 feet.
		142 feet.

It will be seen from the two preceding sections that the strata change considerably in short distances. In the last section the intermediate beds are entirely absent.

SECTION 14.

Three miles northwest of Rock House, northeast of Dockum:

1.	Limestone, top of Plains	10 feet.
2.	Reddish clay	10 feet.
3.	Reddish sandy clay	180 feet.
		200 feet.

For further sections of the Tertiary reference is made to the general statement preceding this.

It has been suggested that the formation of the Staked Plains was once continuous from the mountains in New Mexico to the beds in Fayette county, fifty miles below Austin. This seems to me, however, to rest on nothing but the assumption that the beds of the Staked Plains and the Fayette beds are the same, of which, so far as I know, no proof has been offered. The Fayette beds lie below the "Coast Clays" and the more recent limestone and pebble deposits, and above the uppermost stratum of the Marine-Tertiary, and have been correlated with the "Grand Gulf" of Hilgard, by Dr. Penrose, in the First Annual Report of the Texas Geological Survey, who based his conclusions upon personal examination of the strata and a collection of a great deal of material.

The Staked Plains have not heretofore been studied in anything like a connected or systematic way, and have been seen only at widely separated localities. During the past year's field work sections of the strata have been made at a great many places and on all sides of the high plateau, and they afford no evidence of identity with the Fayette beds, either of a lithological or paleontological character. Indeed I see no evidence whatever that the Blanco beds ever extended much further eastward than the present eastern escarpment of the Staked Plains. There is certainly no remnant of the formation on any of the high hills or mountains east of the present Plains, and besides it is only the upper part of the Blanco beds that were deposited upon the Cretaceous along the eastern side of the Plains. Had it been the lower beds only that remained it might have gone to show that the others had been destroyed by erosion and that a deep sea had once covered the area.

Another fact going to show that the shore-line was not far east of the present limits of the Plains is that while the Tertiary formation as a whole thickens towards the northwest, it is the lower beds only that thicken. The upper bed of limestone is about the same at all places.

There is direct proof, moreover, that there was certainly an old shore-line during the early part of the Staked Plains Tertiary, extending from a point where the east line of Garza county crosses the Double Mountain Fork of the Brazos river, and running thence in a southwesterly direction to the Pecos river. Along that line the lower beds of the Tertiary lie *against* the high Cretaceous bluffs to the southward; and the same may be said of it at the head of Fossil creek near Tucumcari Mount, New Mexico. The Tucumcari beds, which are Cretaceous, have only the upper limestone of the Blanco beds on top at their most northern occurrence, but further southward, where they form part of the escarpment of the Staked Plains, the lower beds are found resting against and upon the Cretaceous beds.

CRETACEOUS.

The Cretaceous strata underlie the southern part of the Staked Plains, and form part of the escarpment on the eastern and southwestern sides and for a very short distance along the northern side in the vicinity of Mount Tucumcari, New Mexico. The formation is also seen at places as inliers in the midst of the Staked Plains.

The Cretaceous, wherever seen, rests directly upon the Triassic, and is practically conformable in stratification with it, having a slight dip to the southeast.

A line drawn from a point on the Double Mountain Fork of the Brazos river, where it crosses the eastern line of Garza county, and running thence southwestward to the southeast corner of Reeves county, on the Pecos river, would represent the northwestern extension of the

Cretaceous formation, as it now exists under the Plains. The strata do not show all along this line, being covered almost continually with the Tertiary, and can only be seen at a few places, but in a great number of wells put down north of that line only the Tertiary strata were found. At Odessa, on the line of the Texas and Pacific Railroad, a well was sunk several hundred feet, and it was found that the Tertiary rested directly upon the red clays. At Deadman's cut, west of Odessa, a bed of Cretaceous occurs with a small *Gryphæa*, probably the small form of the *Gryphæa pitcheri*, Morton.

At the eastern escarpment of the Plains the highest beds of the Cretaceous are the Caprina limestone, resting on the *Exogyra texana* and *Gryphæa* bed, and below that the Trinity sands. The extreme northern occurrence is at the Double Mountain Fork of the Brazos river. On the south side of the river a hill, three hundred and seventy feet high, stands with a bold perpendicular front, facing the north and northwest. The lower part is Triassic, but about one hundred and fifty feet is Cretaceous, with about three feet of Tertiary limestone on the top. On the north side of the river, directly opposite this Cretaceous escarpment, are hills of similar height with the same Tertiary limestone on top, but the Cretaceous is wanting, and there is about seventy-five feet of Tertiary resting directly upon the Triassic. The Triassic strata are about the same on both sides of the river.

The structure of the high hills on the south side of the river, four or five miles west of the Cretaceous hill mentioned, is the same as that of those on the north side, and the same condition exists. On the head of Morgan's creek, in the northern part of Howard county, but south of Gail, between the Colorado river and the Double Mountain Fork of the Brazos, the Cretaceous strata again appear between the Tertiary and Triassic.

From the Double Mountain Fork northward to the Canadian river the Tertiary rests upon the Triassic. There is not a single place where there is any Cretaceous between them, but in the lower Tertiary beds at different places water-worn fossils of the Cretaceous, generally *Gryphæa pitcheri*, are often found.

From the northeastern corner of the Staked Plains near the Canadian river to the west line of the State there is no Cretaceous, and the only place where the Cretaceous is found along the northern escarpment is at the head of Fossil creek, in the vicinity of Mount Tucumcari, New Mexico, where there is an exposure a few miles in length.

The formation there has been described under the head of Tucumcari beds, and is much later than the beds anywhere along the eastern escarpment of the Staked Plains. If the Lower Cretaceous was ever deposited at that place it had been entirely eroded before the later deposition. This bed was placed by Professor Jules Marcou in the

Jurassic, but the fossils show very plainly that it is Cretaceous, and not earlier than the Fredericksburg division.

The Cretaceous formation does not occur anywhere along the western escarpment of the Staked Plains, nor until we reach Castle mountain, in Crane county, where the beds are all lower than the Caprina limestone, the base of which is probably the top of the section, which would indicate a considerable thickening of the beds towards the south.

West of the Pecos river, at Kent, a station on the Texas and Pacific Railroad, the Cretaceous occurs in hills three hundred and eighty feet high. The top of the section is the Arietina clay, and near the bottom we found *Ostrea quadriplicata* and other fossils of the Washita division. These beds rest upon and against the igneous rocks of the Davis mountains. In all the country east of the mountain range and west of the Pecos river, there is no Cretaceous after leaving Tucumcari until these beds are reached, just south of the southern end of the Guadalupe mountains.

TRIASSIC.

The Triassic formation is the basal part of the escarpment of the Staked Plains on all sides. It is composed of clays, sandstones and conglomerates, and lies unconformably upon the Permian. In all parts of the area where it has been examined, it has a slight dip to the southeast.

Mr. N. F. Drake has prepared a report upon this formation, and reference is made to it for further description.

ECONOMIC GEOLOGY.

WATER.

Formerly it was supposed that it would be very difficult to get water on the Plains. The first roads and trails made by the Americans across the plateau were from the Horsehead crossing of the Pecos river and the mouth of the Delaware to Big Springs. The distance between these points is about one hundred and sixty-five miles, and between them no permanent water was found, and only immediately after the rains was any water standing in the shallow lakes, which could not be relied upon, as evaporation is so great that the pools soon dry up.

During the time of the great immigration from the east to California, just after the finding of gold in that State, thousands of cattle and scores of people perished for lack of water in attempting to cross the Plains. It has been demonstrated more recently, however, that shallow wells can be had everywhere at moderate depth, that will furnish practicably inexhaustible water. Their depth is from twenty to three hundred feet according to locality. At the base of the Cretaceous formation is a bed of sand and gravel known as the Trinity sands, and wherever it extends under the Staked Plains abundance of water is always found in it. There is also a water-bearing stratum at the base of the Tertiary formation, and it is only necessary to pierce this stratum in order to secure a bountiful supply of good water.

The entire area of the Staked Plains is covered by one or the other of these formations. The particular area covered by each will be more fully described in another place in this report.

The difference in the depths of these wells at which the water-bearing beds are reached, results from the fact that the upper strata are thicker in one place than in another. The Tertiary thickens toward the northwest. At Big Springs it is not over twenty feet thick, while in the vicinity of Tucumcari it is not less than three hundred feet, so it may be stated as a general proposition that water will be found at greater depths towards the northwest. Hundreds of wells have been put down on all parts of the Staked Plains, and I have never heard of a single failure to secure water where the depth was sufficient to reach either of the water-bearing beds mentioned.

The dip of the strata comprising the upper Plains formation is from northwest to southeast, and the water in the water-bearing beds flows with the dip. There are places where these beds have been cut into by the canyons, and if an attempt should be made near one on the east or south side, there might be a failure to obtain water, but it has been demonstrated in several instances that an abundant quantity could be had a mile or two away.

The water in the shallow wells generally rises several feet above the water-bearing stratum, and stands at that height. This has been thought by many to be an indication that artesian water would be found by sinking the well to a greater depth; but they are mistaken, because the water bearing stratum reached in these shallow wells lies at the base of the catchment formation, and the flow and pressure of water in any lower bed could not be indicated by the pressure found in this one.

LAKES AND POOLS.

At many places there are depressions or basins in which water collects during the rainy season and remains several months. The origin of these basins is unknown. They are a peculiar feature of the topography of the Plains, some of them being as much as twenty or thirty feet below the surrounding level; but generally they are only a few feet below. Their sides are generally a gentle slope. I remember but one of many examined having abrupt sides, showing the beds composing the strata; and in some respects that basin presented different conditions and probably ought not to be classed with the others.

It has been suggested that these lakes might be made permanent storage reservoirs by dredging them out, and by confining the water to a smaller area prevent a too rapid evaporation; but the danger to be apprehended is, that the beds below the present bottom would not be impervious and at once drain off the water. A few experiments would test the matter.

These lakes often comprise several hundred acres, and many of them are covered with tule, and a peculiar kind of grass which makes an excellent hay when cut at the proper season.

SPRINGS.

All the rivers along the eastern side of the Plains are supplied with water by springs mostly from the base of the Cretaceous and Tertiary; but in some instances from the Triassic.

The following is a description of some of them:

BIG SPRINGS.

These springs come from the Trinity sands and issue beneath a massive bowlder of limestone, containing many *Gryphæa pitcheri* and *Exogyra texana*, about one hundred and fifty feet below the bed of the same limestone on the surrounding hills, and seems to have dropped down in a gulch in the Trinity sands washed out by the waters flowing from the spring. Water which comes down a ravine above during rains and falls over the bowlder has cut out a basin from ten to twenty feet deep and thirty feet wide, in which the water usually stands. This spring is not like those at the heads of the Concho rivers, whose waters flow off in bold running streams. The water in this spring sinks into the sand and gravel, flowing only in times of rainy weather. There is suffi-

cient water to supply the town of Big Springs and the machine shops of the Texas and Pacific Railroad, located at this place. The pumps are placed at the springs and the water is forced into a tank on a hill between the springs and the town, and delivered at the town from mains. The springs furnish 100,000 gallons of water per day.

MOSS SPRING.

Six miles east of Big Springs is a large spring of pure fresh water known as Moss spring. The water runs into a large pool below and sinks into the sand. This spring is probably one hundred feet lower than Big Springs. The Cretaceous and Triassic formations have both been eroded entirely here and a conglomerate formed of the broken down material, from which the water issues.

In the vicinity of Moss spring are several other small springs that are of no particular note.

WILD HORSE.

Thirteen miles north of Big Springs are Wild Horse springs, which furnish only a small amount of water from the base of the Tertiary formation.

At these springs the fossil remains of a large animal, probably a mastodon or mammoth, were unearthed a few years ago, of which I saw only the fragments of the bones of one leg.

ARTESIAN WATER.

A very important question to be determined is the probability of obtaining artesian water on the Staked Plains. What I mean by "artesian water," is water that will flow at the surface from deep sources. As early as 1853, when a survey was made across these Plains for a railroad route from the Mississippi river to the Pacific coast under the direction of the Secretary of War of the United States, a report was made stating that it was possible artesian water could be obtained, and an effort was made by Captain Pope, in 1858, to bore an artesian well, about fifteen miles east of the mouth of Delaware creek; but failing to secure flowing water, no further effort was made by the Government.

A great number of wells have been bored, ranging in depth from fifty to three hundred feet, and in all of them water has been found, and in many it rises several feet above the water-bearing stratum. It was thought and asserted by the well-borers that if they had continued boring flowing water would have been obtained.

Certain conditions are absolutely necessary in order that flowing water may be obtained at a given point, and if any one of these conditions are wanting, though the others exist, water will not flow. Heretofore so little has been known about these conditions in connection with the Staked Plains, no definite conclusion could be reached as to the probability of artesian water being found there. In a report by

Professor E. T. Dumble, State Geologist of Texas, in 1890, to the United States Secretary of Agriculture, on the existence of artesian water west of the 97th meridian, he says: "Our knowledge of its (the Staked Plains) geology is too limited to permit anything but the most general statement. * * * It will require a considerable amount of work in eastern New Mexico to decide the matter finally."

During last summer I made extensive examinations of the country, both in Texas and eastern New Mexico, for the purpose of collecting such facts as would furnish a basis for a definite conclusion upon the subject, and found that the following geological formations lie one above the other, extending under a part or the whole of the Staked Plains: Tertiary, Cretaceous, Triassic, Permian and Carboniferous.

No artesian water can be found in the Tertiary, for the reason that there is no continuous impervious strata above the water-bearing stratum. There is an abundance of water at the base of that formation, and the elevation is sufficient to force it to the top of the Plains along the eastern edge if there was an impervious bed above and below; but there is not, and the canyons cut across the strata to the very base, so that water in the water-bearing stratum north or northwest of them finds its exit into them, and therefore cannot rise above.

The water that rises in the shallow wells is found in this water-bearing stratum at the bottom of the Tertiary, and there is no relation between it and water that may be found at a lower depth; therefore the fact that the water in some of these shallow wells rises several feet is no indication that water found below and in a different formation would rise to the top. The small flowing wells reported from the Staked Plains have been bored in the canyons, where the erosion has not yet cut through the entire Tertiary strata, and where the top of the well is much below the top of the Plains.

The next formation below is the Cretaceous. It does not extend to the western or northern escarpment of the Plains, but is only below a part of the southeastern area. No artesian water can be found in it for the reason that there is not sufficient elevation to force the water to the top of the Plains, even if the other conditions were favorable. There is no catchment area exposed at the surface anywhere along the northwestern border of the Cretaceous, for it is overlaid by the Tertiary. This, however, would not prevent there being plenty of water in the sands at the base of the Cretaceous to give an abundant supply, for the reason that the water-bearing stratum of the Tertiary rests directly against the Trinity sands along the old northwestern shoreline of the Cretaceous, and all the water that is in the Lower Tertiary is at once taken up by the Trinity sands and carried by them to the lower level.

That there is a large quantity of water in the lower beds of Cretaceous is shown by the fact of its being found everywhere in shallow

wells, and by the amount that flows from the many large springs along the Concho rivers, all of which have their source at the base of this formation; but deep canyons have also cut across these beds, which prevent the water receiving pressure from the northern extension of the formation under the Staked Plains.

The next underlying formation that could be looked to for artesian water is the Triassic. This formation is the base of the escarpment of the Staked Plains on the east, north and west. It has a slight dip to the southeast, and if the other conditions were favorable there is sufficient elevation of the northwestern outcrops to force water to the top of the plains along the eastern half. There is water in some places in the Triassic strata, but the water-bearing bed is not homogeneous, is not a continuous water-bearing sheet, and there are places where it is cut into by the deep canyons, the water collected north or northwest coming out in springs along their sides.

The next underlying formation is the Permian, which outcrops on all sides of the plains except the south. On the eastern, it dips to the northwest, and on the western, to the southeast. The Staked Plains may therefore be said to be in a Permian basin. Along the foot of the mountain range west of the Pecos river and south of Roswell, in New Mexico, the Permian is overlaid by the Tertiary.

The Pecos river has cut down into the Permian strata from the mountain range to the furtherest extension south of that formation. Therefore any western elevation that a water-bearing stratum may have would not be continuous to the Plains, and the elevation of the strata at the Pecos river would be the limit that could be taken into calculation in estimating the probability of artesian water on the Plains having a western source. The highest point along the line of the Texas and Pacific Railroad is at Duro, which is thirty-one hundred feet above sea level. The bed of the Pecos river at the mouth of Seven Rivers, in New Mexico, has the same elevation, so that any stratum of water that would flow at Duro, must necessarily have its catchment area north of the mouth of Seven Rivers. Then if we take into consideration the friction of water in passing through any material found in the Permian, it would reduce the chances of reaching the top of the Plains, even if such a stratum existed, except at the extreme southeastern side. A well was put down at Big Springs six hundred feet through the red clays of the Permian, and the water rose to within four feet of the top of the well, which is fifty feet above the railroad track. The source of this water is probably along the Pecos river.

At Odessa, whose altitude is twenty-nine hundred feet above sea level, a well was put down eight hundred and thirty-two feet, passing through nearly seven hundred feet of the Permian red clay, without finding water. Several wells have been put down as deep as four hun-

dred feet after reaching the red clay of the Permian, at different places in Howard county, but without finding water.

There is another fact to be taken into consideration in regard to water found in the Permian—all of it would be so highly impregnated with chloride of sodium, and often with other salts, that it would be unfit for any purpose. Even if a bountiful supply of flowing water could be obtained, the chances are that it would be worthless.

The next formation is the Carboniferous. It outcrops below the Permian the entire extent of that formation east of the Plains, and also west of the Pecos river. On the east it dips to the northwest, and on the west toward the southeast. The beds of this formation are nowhere cut into by the Pecos river, and the elevation of any catchment area west of that river is sufficient to cause a flow of the water at the surface anywhere on the Staked Plains. I know of no faults or breaks in the strata that would prevent the flow when it is once in the stratum, and the probabilities are that no such breaks exist. There is known to be artesian water in the Carboniferous formation west of the Pecos river, and there is no reason known to me why it does not flow or extend under the Staked Plains. At Toyah, twenty miles west of the Pecos river, on the line of the Texas and Pacific Railroad, at an altitude of twenty-nine hundred and seventy-five feet above sea level, water was found in the Carboniferous at a depth of eight hundred and thirty-two feet, which flows three hundred gallons per minute, and would probably rise to a much greater height, enough at least to cause it to flow at the highest point of the Staked Plains, or anywhere east, if the water-bearing stratum should be penetrated. The only question then remaining is the depth at which this water could be reached. This can only be approximated. Any boring would first have to pass through the Tertiary, or Tertiary and Cretaceous, about two hundred feet; then the Triassic, two hundred and fifty feet; then the Permian, which, on the eastern side, is two thousand feet; and then at least one thousand five hundred feet of the upper part of the Carboniferous, making in all a distance of at least four thousand feet, before there would be any chance of reaching flowing water, and a much greater depth might be necessary.

From the facts as I now understand them, I think there is no probability of obtaining artesian water at any reasonable depth on the Staked Plains. The cost would be too great to be profitable, and if reached, it is probable that water in the Carboniferous strata would be charged with sulphur, as is that at Toyah and at the head of Delaware creek.

The artesian water obtained at Pecos City does not pass under the Staked Plains, and is probably confined to a comparatively restricted area.

DESCRIPTION OF COUNTIES.

The following brief description of the several counties on the Staked Plains is intended to direct more particular attention to their water supply than to their other natural resources.

There is great similarity in the topography and soils of certain areas. A range of counties along the western border are quite sandy. The northern counties are very level, have a dark soil, and are covered with mesquite grass but no timber of any kind, while the southern counties are partly sandy with mesquite brush, and partly dark soil covered with mesquite grass.

ANDREWS.—This county is situated at the southeast corner of New Mexico. It is still unorganized and is occupied only by ranches for stock raising. There are about seventy wells in the county, ranging in depth from fifty to one hundred feet. The water rises in all much above the point at which it was reached. They are generally bored through about the same beds as follows:

1.	Soil	15 feet.
2.	White limestone	20 feet.
3.	Bluish sandy clay	10 feet.
4.	Conglomerate	30 feet.
5.	Sand	8 feet.

The water is in unlimited quantities as far as tested and of excellent quality. The soil is rather sandy, and in many places quite so.

Shafter's lake, sometimes called Ranger lake, is in the northwest corner of this county near the New Mexico line. Five Wells are in the northwestern part of the county, situated in a ravine, all within a short distance, from six to eight feet deep and have four or five feet of water. There is a salt lake about ten miles south of these wells.

ARMSTRONG.—This county is on the line of the Fort Worth and Denver City Railroad, at the eastern escarpment of the Staked Plains, about three hundred miles from Fort Worth. Palo Duro and Mulberry canyons run through it. With the exception of these canyons and a few others of less note the country is very level. The soil is red and black sandy loam. The county is being rapidly settled with farmers, and their success has been most satisfactory. Plenty of water is found in wells ranging from twenty-five to one hundred and fifty feet in depth. There are broad shallow lakes or ponds at many places that have water in them for a few months in the year. There is very little timber in the county except cedar and shinoak in the canyons.

BORDEN.—This is the first county north of Big Springs. About half or less of its area is on the high Cretaceous plateau of the eastern border of the Staked Plains. Gail, the county seat, is situated at the foot of the plateau, half a mile south of a small creek. The following section was made half a mile west of the town, beginning at the top:

1.	Caprina limestone	10 feet.
2.	Soft limestone	20 feet
3.	Massive limestone	15 feet.
4.	Massive limestone, good building material	10 feet.
5.	Bluish clay	20 feet.
6.	Gryphæa beds, sandy	4 feet.
7.	Pack sand, gravelly at bottom	40 feet.
8.	Micaceous sandy clay and red clay to bottom	81 feet.

By barometric measurement the top of the Caprina limestone has an altitude of 2600 feet.

The wells in the eastern part of the county are generally dug in the drift from the plains, varying in depth from ten to twenty feet, and ordinarily furnish sufficient water for domestic purposes. Below the conglomerate, the beds of the Permian appear, and they are very thick, and any water obtained from them would probably be salty. I heard of no deep wells on the high plateau. Water could be obtained there at a depth of about one hundred and fifty feet, as there is always water in the Trinity sands, which here are about that distance from the top of the Plains, as shown by the foregoing section. There are several springs in the western part of the county which have their source in the Trinity sands and the Triassic sandstone and conglomerate. There are other springs whose water comes from the drift. None of them are large, but generally furnish a constant flow of pure water. The timber here is confined to the creeks and mesquite flats, but furnish sufficient fuel for domestic purposes. The cedar on the bluffs of the hills and canyons is sufficient for fence posts. The county is being rapidly settled by farmers.

BAILEY.—This county is situated on the western border of the State, next to New Mexico, on the high plateau of the Staked Plains, and is entirely covered by stock ranches. It is unorganized. Water is obtained in abundant quantities at a depth of two hundred feet, there being such uniformity in the surface of the country that there are no inequalities of the strata above the water bearing beds. The following named lakes are found in different parts of the county: Negra, Hunt's, Salt, Vietas, and several others of less note.

BRISCOE.—This county is on the eastern escarpment of the Staked Plains, with only a part on the high plateau. Palo Duro canyon runs through it from northwest to southeast. In the canyon there is always running water, and water can be obtained in wells on the high plateau at about two hundred and fifty feet; in the canyon it can be reached at a much less depth, very often at a few feet. There are quite a number of settlers in this county, but it is very largely given up to stockraising. There is plenty of cedar timber along the canyons for all necessary purposes. The soils are of two kinds—the red sandy loam of the lower levels, and the black sandy land of the Staked Plains, each of about the same fertility.

COCHRAN.—This county is situated on the west line of the State, adjoining New Mexico. It is unorganized, and devoted entirely to stockraising. There are only a few wells in the county, but all of them furnish an abundant supply of water. Lake Quemas, sometimes called Quemada, is situated near the western border. It is a circular lake, about three-fourths of a mile in diameter. There are several large springs in the banks, which supply it with water.

CROSBY.—This county is on the head waters of the Salt Fork of the Brazos river, entirely on the high plateau of the Staked Plains. It is mostly devoted to stockraising, though quite a number of farms have been opened during the past few years with satisfactory results. There are about two hundred wells in the county, ranging in depth from seventy-five to three hundred feet, the deepest in the southern part. I visited quite a number of wells in the pasture of the Kentucky Cattle-raising Company, whose ranch is in the southern part of the county, situated on both sides of Blanco canyon. These wells are generally about three hundred feet deep, the water rising in them sixty feet. Windmills are used to pump the water, which is found to be inexhaustible by this method, and no other has been tried. Blanco canyon runs entirely across the county, and at Mount Blanco is two hundred and fifty feet deep and about one mile and a half wide. The bluffs on either side are quite precipitous. White river, a clear, beautiful stream of pure water, runs through this canyon. The waters come from numerous springs that issue from the base of the Plains formation. At the falls of White river, at low water, by measurement, thirteen million gallons of water pass over per day. Below the falls, within ten miles, are many springs, some quite large, and there is probably as much water from them coming into the canyon below as above the falls. The canyon has cut down only to the base of the Tertiary above and at the falls, which are twenty-four feet, while below them the sandstones, conglomerates and red clays of the Triassic are exposed. Above the falls the springs come from the sands at the base of the Tertiary, while below many of them issue from the conglomerate of the Triassic. Nearly all of the springs are on the west side, the canyon running nearly north and south, the dip of the strata being toward the southeast. Spring Creek canyon, five or six miles long, is on the south side of the county. In this are a number of fine springs coming from the base of the Tertiary. These waters flow into the Salt Fork of the Brazos. Yellow House canyon, in which there is always more or less water, crosses the southwestern corner of the county.

CASTRO.—This county is organized, though principally occupied by large cattle ranches, with about two hundred settlers. Dimmitt, the county seat, is in the center of the county. There are about thirty wells, ranging in depth from twenty-five to one hundred and fifty feet. The water is obtained in sand and limestone, is practically inexhaust-

ible, free from salts of any kind, and is very cold. There has been no attempt to find water by deep boring. The soil is mostly black sandy loam, but with so much clay in many places that it will roll up on a wagon wheel like the black waxy of central Texas. There is enough sand, however, in all the lands to make a plow scour when plowing. The entire county is very level. There are no canyons or breaks of any kind, except a few draws and depressions at various places called "wet weather lakes," in which a peculiar kind of grass grows that when cut at the proper time makes an excellent hay. There is no timber of any kind in the county, not even mesquite roots. All the fuel has to be hauled from Amarillo.

DAWSON.—This county is unorganized, and is occupied by cattle ranches. There are about fifty wells, ranging in depth from seventy to one hundred and fifty feet, in some of which the water is salty. This county is near the old northwestern shore-line made by the Cretaceous formation, near which it has been observed water was not so easily obtained as away from it on either side.

DEAF SMITH.—This county is unorganized, occupied by cattle ranches, and situated along the western border of the State next to New Mexico. Water is found in wells at a depth of thirty to one hundred feet. There are springs in the canyons, generally on the north and northwest side. Terra Blanco canyon, a tributary of Palo Duro, runs through the county, having its head in New Mexico. The water in this canyon stands in holes a mile or two in length and often twenty feet deep. In these ponds are some very fine fish.

FLOYD.—Floyd county is in the midst of the Plains. The land is level and of excellent quality. At the time of my visit there were about one hundred and fifty wells, in depth from thirty to fifty feet, with water inexhaustible by pumps run by windmills. Some of the ranches have small farms irrigated by water from these wells, pumped into reservoirs and then turned on the land when needed. Blanco canyon passes through this county. In it water is found a few feet from the surface. There are hundreds of small lakes that usually have water in them during the summer months. There are quite a number of farmers, who have found it possible to raise good crops without irrigation. The soils are generally black sandy, covered with curly mesquite grass.

GAINES.—This is the second county on the western line of the State north of the southeast corner of New Mexico. It is unorganized and entirely occupied by cattle ranches. In the northeastern part is lake Sabinas, nearly six miles long and four miles wide, the water of which is salty; but at the north end plenty of good fresh water can be obtained, while that in the shallow wells at the south end is salty. Water can be had at a few feet from the surface by digging anywhere near the

margin of the lake. Nearly due east of this, at a distance of thirty-five miles as measured by the odometer, is the head of Tobacco creek, a tributary of the Colorado river, and nearly southeast, at a distance of thirty-two miles, is Lake Cuates or Tahoka, often called Cedar lake. Five miles west of Five Wells is the first of a number of wells called Ward's Wells. They are in a ravine or narrow valley running northwest and southeast, and range in depth from four to fifteen feet. In two ravines running into the main canyon are quite a number of other shallow wells known as McLean's Wells and Seminole Wells. There are other salt lakes in the county.

GARZA.—This county is at the eastern escarpment of the Staked Plains. The Double Mountain Fork of the Brazos river runs through it from west to east, and Yellow House canyon through the northern part, reaching the Double Mountain Fork east of the eastern line. The eastern part is quite broken, and mostly given up to stockraising. We found several springs of good water issuing from the Triassic sandstone at the base of the Plains. There is a little timber on the creeks and canyons and mesquite in the valleys.

HOWARD.—This county is only partly situated on the Plains, being at the extreme southeast corner. Big Springs is the county seat. There are a large number of wells ranging in depth from fifteen to one hundred and twenty-five feet, most of them having good water, but in some the water is so highly impregnated with common salt as to be useless. At the town of Big Springs two deep wells have been bored, one 700 and the other 300 feet deep. In both the water is so salty as to be unfit for use. In the deepest the water rose to within four feet of the top. The strata passed through in boring this well was principally the red clay of the Permian, and when that clay is reached in boring wells there is very little prospect of getting other than salt water. The thickness of the Permian beds at this place is over two thousand feet, and not much likelihood of getting flowing water at any depth. In the western part of the county are a number of salt lakes that have a crust of pure salt over the entire surface during the dry months, when the water is mostly evaporated. At the time of our visit the crust of salt was about two inches thick and as white as snow, being almost entirely free from dust or sand. This salt could be collected at such times in large quantities and easily prepared for market. The following is a complete analysis of a sample of salt taken from one of the lakes:

Water	4.09
Alumina	.89
Ferric oxide	Trace
Sulphuric acid	7.41
Magnesia	2.24
Chlorine	49.72
Sodium	32.19
Soda	2.67
	99.21

There are a number of fresh water lakes that are generally dry after July. The soil is well adapted to agriculture and fruit raising, and there are a large number of farms.

HOCKLEY.—This county is in the second tier east of the west line of the State and northeast of the southeast corner of New Mexico. It is unorganized and devoted to stockraising. There are about one hundred and fifty wells, in depth from seventy-five to one hundred and fifty feet. In all the water rises above the point where it is reached, sometimes as much as seventy-five feet. There are three flowing wells in a canyon running into Yellow House canyon, the water in which is reached at a hundred and twenty feet. The flow is small, not more than four or five gallons per minute, or seven thousand two hundred gallons per day. The cause of the flow is local, and the water will only reach the surface in the canyon. Lake Caronado, a large lake of constant water fed by springs, is in the southeastern part of the county.

HALE.—This county is situated in the midst of the Staked Plains. It is a level prairie from center to circumference, and every acre can be cultivated. The only water courses are slight depressions called "draws" which traverse the county from the northwest to southeast. Running Water is a bold spring branch in one of these draws, which runs for twenty miles and then sinks into the sand. The drainage consists of a succession of saucer-shaped basins of various sizes without any outlet, in which every drop of rain that falls is taken up by the soil. In some of them are lakes which hold water part of the year, and water can always be had by digging from ten to twenty-five feet. In some there is also a growth of lake grass, which makes an excellent hay. The largest lake in the county is known as Cora lake, in which there is water all the year. There are about one hundred and fifty wells, the deepest not over one hundred and fifty feet. Some irrigation has been done with water from shallow wells elevated by windmills, and good crops reported.

LYNN.—This county is in the midst of the Staked Plains. Wells range in depth from fifty to two hundred and eighty feet. The deepest are along the southern border. Water rises in all, and in some as much as forty feet. Tahoka lake is near the center, about seventy miles a little west of north from Big Springs, thirty-two miles nearly due north of the head of the Double Mountain Fork of the Brazos, and thirty miles west of the head of the Colorado river, as measured by the odometer. The two bodies of water composing this lake are in a depression of the Plains, both salty, without any visible outlet, and about three miles long and one-half mile wide, with several fresh water springs near. They are also known by the name of Cuates, and are so marked on some of the maps. Double Lakes are about eight miles from Tahoka, and about the same size. One of them has salt and the other fresh water, and both have

fresh water springs along their margins. They are sometimes known as Blanco Lakes. There are several other smaller lakes in the county.

LAMB.—This county is in the second tier east of the west line of the State adjoining New Mexico, and is unorganized. There are about twenty-five wells in the county. The Syndicate Cattle Company are making arrangements to bore an artesian well on their property, and will go to the depth of four thousand feet if necessary to get flowing water. Casa Amarilla lake is situated in the southwest corner, forty-two miles almost due west from the head of Double Mountain Fork of the Brazos river, as measured by the odometer, and about three miles long and one-half mile wide. The water is highly impregnated with salt and alkali. It drains the country from all directions and is fed by springs. Fresh water may be had by sinking pits near the margin. Lebos lake is about eight miles north of Casa Amarilla, and has permanent water.

LUBBOCK.—This county is organized, and has about fifty wells, ranging in depth from one hundred to one hundred and fifty feet. Yellow House canyon, in which the wells are very shallow and furnish an abundance of water, traverses the southeastern portion of this county. A number of springs supply this canyon and the smaller gulches that come into it from both sides. There is one artesian well in the vicinity of White Lake which has a small flowing stream, and another is reported in a draw of Yellow House canyon.

OLDHAM.—This county is on the western border of the Staked Plains, less than one-half on the high plateau. There are numerous springs along the northern escarpment, the water of which comes from the base of the Tertiary, which here rests directly upon the red clays of the Triassic. Wells on the high plateau are from two hundred to two hundred and fifty feet in depth. There is a well flowing fifteen gallons per minute in a canyon three hundred feet below the top of the Plains. The water was reached at a depth of two hundred and thirty feet.

PARMER.—This county is situated on the west line of the State adjoining New Mexico. It is unorganized and entirely devoted to stock-raising.

POTTER.—This county is situated along the northern border of the Staked Plains, a part only on the high plateau. There are a great number of wells, ranging in depth from two hundred to two hundred and twenty-five feet. A number of springs break out in the canyons, two hundred feet below the top of the Plains, the water coming from the bottom of the Tertiary formation. Water is found also in the Triassic sandstone. There are a great many farms in this county, and it is settling up rapidly.

RANDALL.—This county lies directly south of Potter county, and is unorganized. There are quite a number of wells, ranging from two

hundred to two hundred and twenty-five feet. Palo Duro canyon runs through from east to west. In it are a great number of springs, and a stream of water runs all the year.

SWISHER.—This county is entirely on the high plateau. The wells are generally about one hundred and eighty to two hundred feet deep, the water rising half way to the top. Those in the side canyons of the Palo Duro are not more than eighteen or twenty feet deep.

TERRY.—This county is situated in the midst of the Staked Plains, in the second tier from the east line of New Mexico. There are about twenty-five wells, ranging in depth from one hundred to one hundred and fifty feet, all having an abundant supply of water, which rises several feet above the point where it is reached. It is raised by windmills, and is used for watering stock, the whole country being devoted to stockraising. There are several lakes, the principal ones known as Rich, Omboga and Cunningham's.

YOAKUM.—This county is on the western border of the State adjoining New Mexico, is unorganized, and devoted to stockraising. There are only a few wells, ranging in depth from eighty to one hundred and twenty feet.

MIDLAND is the second county west of Big Springs on the line of the Texas and Pacific Railroad. There are several hundred wells, at least one hundred said to be in the town of Midland alone, where they are from forty to seventy feet deep. In the country they range in depth from twenty to one hundred and fifty feet. In some of the canyons, or draws as they are called here, water can be had at only a few feet from the surface. One flowing well is reported, which ought not, however, to be so classed, as it is only about fifteen feet deep. It is said to flow five hundred gallons per minute, but I think that this estimate is too high. The railroad well in the town of Midland furnishes sixty thousand gallons of water per day. Mustang springs are mentioned on some of the old maps as La Laguna. They comprise several large pools or lakes, which are highly saline. Altogether they are about three miles long.

ECTOR.—This county is on the line of the Texas and Pacific Railroad west of Midland. There are about fifty wells, averaging in depth from fifty to one hundred and fifty feet. It is said that in boring to that depth several beds of water are penetrated. The water rises in the wells above the point where it is reached. At the town of Odessa a hole was put down eight hundred and thirty feet in an attempt to reach artesian water. Nearly seven hundred feet was through the red clay of the Permian. The work was abandoned on account of some difficulty with the casing, and no other attempt has been made.

MARTIN.—This county is the first on the Texas and Pacific Railroad west of Big Springs, and it has been settled longer than any county on the Staked Plains. There are a large number of wells, from twenty

to one hundred and fifty feet in depth, the deepest being in the eastern part. Water in great abundance can be had in Mustang draw at a depth of from five to fifteen feet. Mustang springs are four miles south of the line of railroad. At Marienfeld the railroad has a well affording twenty-four thousand gallons per day. Sulphur springs are about thirty-five miles northwest of Big Springs. There are several, nearly all of which contain pure fresh water. One of them is slightly tinged with sulphur, and when they all flow together, and form a large pool below, the water becomes more or less impregnated with it. The water comes from beneath a conglomerate ledge, composed of material from the Cretaceous limestone. The mass is bound together by carbonate of lime and silica precipitated from the water. The owners have built a dam across the ravine a few hundred yards below, making a large deep reservoir for the storage of the water, and at the time of our visit thousands of cattle watered there daily. Soda lakes are situated about four miles north of Sulphur springs. At the time of my visit they were nearly dry, and the water remaining was incrusted over with a layer of salt and soda an inch thick. They are in depressions in the surface without any outlet, and are supplied by the drainage of the immediate vicinity. The following analysis was made of the crust formed by the evaporation of the waters of one of these lakes:

Water	.96
Silica	.30
Alumina	1.46
Ferric oxide	Trace
Sulphuric acid	51.30
Magnesia	.59
Chlorine	4.92
Soda, with trace of potash	41.07
	100.60

AGRICULTURE.

Since the first farms were opened on the Staked Plains the area put in cultivation each year has increased very rapidly, until now some of the counties are largely taken up. I was informed while on the northern part of the Plains that in some of the counties there was not a single agricultural section of school land that had not been taken up. If this is true, the amount of land already taken up for agricultural purposes will be found very large. There are, however, fine districts of land remote from the railroads still unoccupied.

In discussing the agricultural possibilities of any country three things are to be especially considered: First, soil; second, climate; third, rainfall.

SOILS.

The soils of the Staked Plains have been derived principally from the underlying materials of late Tertiary age, and they in turn were derived from the Cretaceous and Triassic. In late Tertiary times where the Staked Plains now are was an inland sea, bounded on the east and south by the Cretaceous formation and on the west by the range of mountains west of the Pecos river. During the early part of this Tertiary time there was great erosion of the Cretaceous and Triassic, and a great redepositing of the material derived therefrom. This material of sand and clay was worked and redeposited in this inland Tertiary sea, until finally when it was drained of its waters there was left a series of beds of this Tertiary material varying from ten to twelve feet on the south to three hundred feet on the north, composed of sandy clays in alternate beds of stratification, but none of them so compact as to be impervious to water.

Whenever these strata are exposed to atmospheric influence it is easily disintegrated, and forms a fixed soil composed of the immediately underlying beds, but so thoroughly had these beds been mixed before their deposition that when they decomposed they formed a soil that is very homogeneous throughout the entire area of the Plains. The soil proper ranges in thickness from two to four feet, determined entirely by local causes.

There is more sand in some places than in others, owing to the fact that the fine sand has been driven from its original locality to some distant point, where from some cause it has accumulated and entered into the composition of the soil.

At other places the soil has a black color, owing to the amount of vegetable matter that has been incorporated in it from the vegetation that has grown at that particular point.

The subsoil is of the same material as that which has gone to make up the present soil, and if at any time any ingredient should become

exhausted from the continual production of one kind of crop, the soil can again be brought to its present state of fertility by the use of the subsoil plow.

The soil is sufficiently porous to take up all the water that falls upon it, and the strata below permit it to pass to base of the Tertiary formation, where it forms a permanent stratum of water. The roots of plants will always be able to reach this supply, because the force of capillary attraction will always bring the water sufficient for plant life to within a short distance of the surface. This soil never becomes as dry and hard as that of some other parts of the State; for almost any day in the year moist soil can be found within an inch or two of the surface.

No extensive collection or analyses of the soils have been made by this department from any part of the area, and the character of them can only be judged by the general appearance, its origin and the growth found upon the land either in its natural condition or since it has been brought under cultivation.

There are about four different kinds of soils, judging from general appearance, on the Plains, and all are found in every county in greater or less amount. The prevailing variety is a rich chocolate loam, very often overgrown with mesquite grass in the southern part; a black sandy, sometimes waxy soil; a red loam, which resembles the soils of the Colorado and Brazos river lands, and a loose red sandy soil.

The rich dark chocolate soil has a more general origin, is generally deeper than any of the others, and is made up from all the others.

The black sandy soil has its origin from the immediately underlying limestone bed of the Tertiary, which is now everywhere found at the top of the Plains where the overlying soils have been eroded, and from the vegetable material that has grown on the land and afterwards become incorporated with the decomposed limestone.

The red loams have their origin largely from the drift material from the Quaternary, with part of that from the Tertiary. The color evidently comes from the clays brought from the Permian and Triassic and the lower beds of the Tertiary.

The loose sandy variety is made largely from the Quaternary and drift by the wind.

NATURAL GROWTH.

It was formerly supposed that the Staked Plains was a wide expanse of desert sand, and was represented and marked on the old maps as the great American Desert. This has been proven utterly untrue, for there are no spots on this wide expanse upon which there was not formerly a luxuriant growth of native grasses. The only place where anything like a desert can be found is in the white sand hills near the southeast corner of New Mexico, which are only about sixty miles long and fifteen miles wide.

There are three principal native grasses on the Plains: mesquite, gramma and bunch grass. The mesquite is most abundant and grows in great luxuriance. It does not lose its nutrition by drying at maturity; stock will winter on it and keep in good condition. The gramma and bunch grasses are mostly confined to the southern area, and are good for pasturage both in summer and winter.

There is no timber except mesquite, and it is generally very low brush, the annual prairie fires having always kept it burnt down.

The best test of the fertility of soil is the practical results realized by the farmer when other conditions are favorable. The following is the average growth the first year of various fruit trees planted at Odessa between the fifteenth of February and the fifteenth of April, and the measurements taken on the ninth of November:

Apples.—Thirty-four varieties planted; average growth, two feet and three inches; some of the limbs grew as much as three feet.

Plums.—Ten varieties planted; average growth, two feet and ten inches; best growth of limb, four feet and two inches.

Peaches.—Twenty-one varieties planted; average growth, two feet and six inches.

Nectarines.—Two varieties planted; average growth, two feet and six inches.

Soft Shelled Almond.—Seven varieties planted; average growth, four feet and one inch; greatest limb growth, five feet and nine inches.

Cherries.—Thirteen varieties planted; average growth, one foot and six inches.

Prunes.—Six varieties planted; average growth, two feet and nine inches.

Locust, bois d'arc, umbrella china and Lombardy poplar each made a growth of from four to six feet; the poplar, ten feet and three inches, and increased in size from one-half inch to three inches in diameter.

At other places the report of trees planted, without irrigation, equaled the above figures. These facts would indicate a good soil, at least for fruit raising.

The following figures are given as the average yield of a farm in Martin county:

Red Mediterranean wheat	15 bushels per acre.
Illinois Chief wheat	16 bushels per acre.
Illinois Swamp wheat	20 bushels per acre.
Nicaragua wheat	15 bushels per acre.
Georgia Red wheat	22 bushels per acre.
Oats	50 bushels per acre.
Rye	12 bushels per acre.
Barley	30 bushels per acre.
Sorghum syrup	160 gallons per acre.

Sorghum, green feed	10 to 15 tons per acre.
Millet	11 tons per acre.
Rice corn	50 bushels per acre.
Corn	15 bushels per acre.

This farm is without irrigation and furnishes a fair sample of what can be raised on the land of the Staked Plains by proper cultivation.

Another important quality of good agricultural soil is its capacity to receive and retain moisture. By reference to the statement showing the origin of these soils it will be seen that they are more or less sandy, and the country being level, with little drainage, all the water that falls in rains is taken up by the soils and stored in strata below, and may be drawn upon by the plant when needed. The soil is sufficiently porous to permit the roots of the growing plants to readily penetrate it in order to obtain moisture and other material necessary. All the facts being considered the soils of the Staked Plains are shown to be well adapted to agriculture.

CLIMATE.

The next thing to be considered is the climate, which includes temperature, length of time between late and early frosts, elevation above sea level, and the humidity of the atmosphere.

The following table gives the average temperature at different places on the Staked Plains:

TABLE SHOWING ANNUAL MEAN TEMPERATURE ON THE STAKED PLAINS IN TEXAS.

Stations.	Elevation.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Ft. Elliott	2500	30.6	36.0	46.0	55.6	63.8	73.0	77.0	74.7	68.2	56.8	42.5	34.4	54.8
Mt. Blanco	3800	43.7	46.3	54.3	61.0	72.6	76.8	78.9	81.0	73.0	61.2	50.6	40.6	61.7
Midland	2775	39.3	46.9	52.1	64.3	77.5	80.0	84.2	81.1	73.3	61.5	48.6	41.7	62.3

The late frosts on the southern part of the Staked Plains are not later than the fifteenth of March, and on the northern part not later than the first of April. It is very seldom that killing frosts come as late as the dates mentioned. The early frosts come on the southern part of the Plains from the middle to the last of October, and on the northern area a little later. Thus it will be seen that there is at least six months in which to plant and mature crops, a longer time than is required to grow any cereals. Corn planted in February or March will ripen and be ready for gathering by September, and cotton planted in April or May will begin to open the last of September. Wheat is planted in the fall and harvested the following June or July.

The elevation of the Staked Plains above sea level is from two thousand six hundred feet on the extreme southeastern corner to four thousand one hundred feet on the northwest.

After the first of June there are no dews, but the atmosphere is dry, both day and night, until the rains come in August and September, and hence crops should be planted so as to mature as early as possible.

RAINFALL.

A certain amount of moisture is absolutely necessary to plant growth, and if that does not reach the soils by rain, then the lacking quantity must be supplied by artificial means. It has been generally estimated that twenty inches of rainfall per annum was the smallest amount that could be depended upon to produce crops of any kind. When below that, it has been thought that irrigation was absolutely necessary.

There are so many other considerations to be taken into account, aside from the actual annual rainfall, that it forms no real basis for such calculations. The question of evaporation and the time of the rainfall would be two very important factors. There is no greater error than to suppose that because a certain locality has more than twenty inches of rainfall there would be no need of irrigation at that place, or because there were less than twenty inches annual rainfall there would be an absolute necessity for it. This may be very easily illustrated. The annual rainfall at Pittsburg, Pennsylvania, is 36.71 inches, and that of Julian, San Diego county, California, is 37.68. According to the generally received theory, there would be no need of irrigation at either of these places. Yet, while no other moisture is needed at Pittsburg, it is absolutely essential in California. The reason of this is found in the distribution of the rainfall. At Pittsburg it is nearly equal each month throughout the year, while in California only about nine per cent of the whole amount of the precipitation falls from the first of May to the last of November, and nearly one-half of the whole falls during January and February.

If the greatest portion of the annual rainfall is during the time of the growing crops, agriculture will be a success with much less than when the greater part of it comes during the winter months. This is the case on the Staked Plains. The average annual rainfall may be put at twenty inches, and the report of the Chief of the Signal Bureau shows that the dry months are in the winter, and the wet and very wet months are in the summer, when the crops are growing, just the time when the moisture is needed.

No definite information has been obtained relative to evaporation, and as the humidity of the atmosphere depends upon the proximity of the ocean, the direction of the prevailing winds, and the character of the intervening country over which the winds must pass, as well as the temperature, it would be, without definite information, impossible to determine anything about the effect of evaporation upon the moisture of the Staked Plains.

Another reason why average crops can be raised with a less amount

of rainfall than at many other places is the fact that at the base of the Tertiary formation, and often in intervening strata, there is a bed of water which, by capillary attraction, is drawn toward the surface, and brought within reach of the roots of the growing plants. All the water that falls on the Plains is immediately taken up by the soil and stored in the underlying beds, and therefore these beds are kept saturated by much less rainfall than where the soil is hard and the drainage carries off the greater part of the water as it falls.

There is no doubt that the average crop of the Staked Plains would be very materially increased by the aid of irrigation. There are ordinarily three sources for this purpose: natural streams, wells or storage reservoirs.

The streams in the canyons crossing the Plains are so far below the level it would be impossible to get the water from them to the upper plateau. The canyons are generally very narrow, yet there are places in them where several hundred acres could be irrigated. One such is in the vicinity of Mount Blanco, in Crosby county, and it is probable that the water in White river would have been so used but that the owners of the cattle ranches oppose it, fearing that the use of the water for irrigation will so exhaust it that enough will not be left for the large number of cattle. Thirteen million gallons of water flow over the falls of White river per day, most of which sinks into the sand a few miles below. It would be impossible to take the water out of the river to the top of the Plains, as the plateau is two hundred and sixty feet above the falls.

The springs are all near the bottom of the canyons, and the same facts apply to them as apply to the streams.

The reasons for supposing it impossible to get artesian water anywhere on the Staked Plains are given elsewhere and need not be repeated here.

The possibility of obtaining an almost unlimited supply of water from shallow wells has already been stated. That this water could be utilized for growing the ordinary crops is certain, but whether it would pay to do so depends upon the cheapness with which the water can be put on the land.

While crops can be raised without irrigation, the great increase in the annual product, and the certainty of making a crop, would warrant considerable outlay in digging wells, making storage tanks and erecting windmills with which to supply the water. It has been estimated that twelve inches of water, in addition to the annual rainfall, would be ample to mature any kind of crop, even in the dryest year.

The following statements are given of some of the efforts that have been made to irrigate from shallow wells:

The Marienfeld Fruit Growing, Gardening and Irrigating Company have two eight inch bored wells one hundred and forty-six feet deep.

From these they irrigate twenty acres planted in fruits and vines. The water is elevated by two twenty-foot windmills, which will raise about two thousand gallons of water per hour. The water is pumped into a reservoir and used thence directly upon the land. It is thought that the wells will furnish water enough for fifty acres or more planted in vines or trees.

Mr. A. Rawlings, living five miles west of Marienfeld, has two bored wells, three inches in diameter, from which he irrigates an orchard and vineyard of twenty acres. These wells are thirty feet deep and have an unlimited supply of water, which is pumped by two windmills ten feet in diameter, and stored in a reservoir of twenty-two thousand gallons capacity.

In the Mustang draw, a few miles south of the Texas and Pacific Railroad, Mr. Glasscock has a dug well three feet square and twenty deep. The water is pumped by a twelve-foot windmill, raising about fifteen hundred gallons of water per hour, which is stored in reservoirs and used on twenty acres of land as needed.

Six miles north of Midland, on the J. C. Curtis ranch, is a vineyard of four acres, irrigated from a dug well thirty feet deep. The water is pumped by a twelve-foot windmill, capable of raising eight thousand six hundred gallons of water in six hours. The water is run into a wooden tank and thence to the land.

Half a mile from Midland Mr. N. S. Worley has ten acres in a vineyard which he irrigates from a well fifty-five feet deep. The water is raised by a twelve-foot windmill, and is run into a clay reservoir and thence to the vineyard.

Mr. J. M. Moody, in the town of Midland, has an orchard and vineyard of five acres. He irrigates it from a well thirty-five feet deep, using a ten-foot windmill to elevate the water, at the rate of eight hundred gallons per hour.

These facts are enough to show that irrigation from shallow wells, with windmills for hoisting the water, can be made a success in growing orchards and vineyards, and as the water seems to be in an unlimited quantity there is no reason why larger areas may not be cultivated in other crops, by simply increasing the number of wells.

It has been estimated that it would cost about eight or ten dollars per acre to put down enough wells and erect windmills sufficient to irrigate the land.

Another source of water for irrigating purposes is storage reservoirs, where the storm water may be collected in either natural or artificial lakes or ponds. Scattered all over the vast area of the Staked Plains are a number of lakes of all sizes up to six miles in extent. Some are salt and some fresh, and all are generally fed by springs, but receive the drainage from every direction. Some have permanent water, but many are dry part of the year, especially those that have only the

drainage water. The lakes, however, are usually situated in a depression in the plains, so much below the level of the surrounding country that it would be impossible to get the water out of them by canals.

The soil is generally so porous that the cost of making artificial tanks would be too great, and the difficulty of getting a regular supply of flood water would prevent their general use if there were no other objections. There are places on the Plains where the water is so near the surface that a storage reservoir could be excavated with a scraper, and the water carried to some of the lands below, but these places are not very numerous, and can only be found along some of the draws.

There will always be some difficulty in irrigating lands at a distance from the source of the water, arising from the porous nature of the soil and its great absorbent capacity. The seepage from the canals will always be very great where the water is attempted to be carried along a ditch in the soil, as the water is free from sediment of any kind to fill up the open spaces in the soil to prevent seepage.

FRUIT GROWING.

At a great many places small orchards have been planted in different kinds of fruits, principally peaches, plums and apricots. They all have a vigorous growth after the first year, and very few trees die if properly planted, after they have once begun growing. Here, as elsewhere, a want of proper care in planting will result in great loss of trees the first year, but once get them through the first season, they adapt themselves to the new conditions and will live without much care or attention. Every farmer can plant an acre or two in fruits, and raise enough for his own use and to spare, and nothing pays better than a small orchard for home use. The orchard will demand only ordinary cultivation to keep the weeds down and trimming at the proper season, and attention enough to keep the stock from eating it in winter. Cows and orchards do not thrive well upon the same land.

There is no doubt about fruit raising for market paying well on the Staked Plains, under irrigation. Within a short distance of the surface of the ground everywhere is an abundant and almost inexhaustible supply of water which can be elevated by windmills at small cost and conducted to the land either in tiling pipes or troughs above ground, without much loss from seepage. One well eight feet square will furnish fifty thousand gallons of water per day, which would be sufficient to irrigate twenty acres in orchard, and probably much more.

If it should be found that a reservoir eight feet square was not sufficient to supply a pump running ten hours per day, the capacity of the reservoir could be very greatly increased by driving tunnels in one or two directions along the water-bearing stratum, and under a compact conglomerate rock which ordinarily lies above it. It would be better to have the storage reservoir below ground than above, as thereby the

large amount of loss by evaporation would be avoided, and all the water elevated by the pump go directly to the land.

The following is a description of such a well at Odessa, and an estimate of its irrigating capacity.

The well is eight feet square, curbed twenty-one feet from the surface. From the curb to the surface of the water it is round, having a diameter of eight feet at the top, twelve feet at waterline, and sixteen feet at the bottom. The depth of water is eleven feet and six inches. This gives a storage capacity of 14,500 gallons. The well is forty-eight feet deep, and the following material was passed through in digging it:

1. Soil	7 feet.
2. Limestone, soft	14 feet.
3. Conglomerate, very hard	16 feet.
4. Sandstone and gravel	11 feet.
Total	48 feet.

The cost was five hundred and sixty-eight dollars. A twenty-foot windmill with a twelve-foot stroke, a five inch double acting railway pump, with tower complete, will be about five hundred dollars. Such a mill would, with the wind blowing twenty miles an hour, throw five thousand gallons of water per hour. It was estimated that such a well and mill would furnish enough water, with the annual rainfall, to irrigate forty acres of land.

VINEYARDS.

The planting of vineyards on the high plateau has not been attempted on a very large scale, but enough experimenting has been done to prove that grapes can be raised in great perfection. More is dependent upon climate for raising grapes than on the nature of the soil. Good soils for grape culture can be found almost anywhere and in any country; but only a few localities, comparatively, have a climate of the character to produce the best results. Where the soil is deficient in any quality for the culture of grapes, the deficiency may be artificially supplied.

Again, one kind of grape which will grow well in one place will not thrive in another and different climate. The temperature of the Staked Plains in winter is from fifteen to twenty degrees colder than it is in Southern California, and no doubt some protection will be necessary to prevent bad results from the cold waves that occasionally pass over them. This can be done by earthing up the vines as they do in the Rio Grande valley. The soil is all that can be desired, being light, porous and very deep, as well as fertile. The mission and raisin grape and some California varieties will thrive best, no doubt, and some of the wine producing varieties will be raised successfully. The raisin grape needs rapid and continuous evaporation while drying, just such an atmosphere in a word as is found on the Plains at the time of the ripen-

ing of the grapes. There are no fogs or dews during this time, and very little chance of rain.

The convenience with which a vineyard can be irrigated will add very materially to the value of the country for grape growing, and the profit can be very easily estimated, based upon what has already been done. Vines will begin to bear the second year. The third year an acre will produce about one thousand five hundred pounds of raisins, and will increase in product until the vines are seven years old, when an acre will yield, under favorable conditions, from one and a half to two tons. One hand can cultivate, prune and irrigate twenty acres. One ton of raisins is worth from one hundred and seventy-five dollars to two hundred dollars, and it costs about fifty dollars per ton to prepare them for market.

The mission grape will yield about two tons of grapes per acre the third year and increase in quantity for several years up to five and six tons. These grapes are worth at the vineyard from two to three cents per pound and always find a ready market. A vineyard of twenty acres, yielding two tons of grapes per acre the third year, would give an income, at two cents per pound, of eighty dollars per acre, or one thousand six hundred dollars for the twenty acres. In six years, with a yield of five tons per acre, would give two hundred dollars per acre, or four thousand for the twenty acres. The same estimate will hold for wine grapes which have been tested in the vicinity of Marienfeld.

Well planted vineyards are worth from three hundred to four hundred dollars per acre after three years.

PRUNES.

The cultivation of prunes has been a success in a small way. I could hear of no large orchards, but those planted showed a vigorous growth and were well fruited. The climate is particularly adapted to the raising of this fruit. The dry atmosphere is of great advantage at the time of drying. The trees are planted eighteen feet apart, which gives one hundred and thirty-four to the acre, and if each tree produces two dollars worth per year would give the sum of two hundred and sixty-eight dollars per acre. They begin to fruit after three years. The prunes are generally free from blemishes, and are not subject to injury from insects.

FUEL.

There are no trees of any kind on the Staked Plains, and fuel will have to be obtained elsewhere. Patches of mesquite grow here and there, and there is no better fuel than dry mesquite roots; they burn readily, make an intensely hot fire, and are easily obtained by digging. It is probable that if the prairie fires are kept out of the country for a few

years longer the growth of mesquite will be very materially increased, and fuel supplied in that way. Such is the mildness of the climate, and the winters are usually so short, that no fuel is required for a large part of the year except for cooking purposes.

No particular effort has been made to grow timber on the Plains except in a small way. It has, however, been demonstrated that several varieties of wood have a rapid growth, and any one who desires can in a few years raise enough fuel for his own use.

NOTES ON THE GEOLOGY

OF THE

COUNTRY WEST OF THE PLAINS.

TUCUMCARI, NEW MEXICO.

Tucumcari mountain is situated in New Mexico, about fifty miles west of the Texas state line, and on the south side of the Canadian river. The mountain is merely a remnant of a once elevated plateau, cut into its present condition by erosion. There are several other peaks of the same character and of the same geological formation in the vicinity—Little Tucumcari, Mount Rivuelto, Pyramid Mount and others.

The north side of Tucumcari mountain is almost perpendicular, presenting a most excellent exposure of the strata from bottom to top. The height is six hundred and twenty feet on the north side, measured with an aneroid barometer. The summit is about two hundred feet higher than the plateau of the Staked Plains, which begins in a bold escarpment at distance of about twenty miles southward.

The following is a detailed section of Tucumcari mountain, begining at the top:

1.		
2.	White clayey limestone	20 feet.
3.	Massive sandstone	60 feet.
4.	Shale	50 feet.
5.	Massive yellowish sandstone	235 feet.
6.	Red sandstone	30 feet.
7.	Blue clay	4 feet.
8.	Purple clay	6 feet.
9.	Arenaceous clay	1 foot.
10.	Blue clay	4 feet.
11.	Purple clay	16 feet.
12.	Light red clay	30 feet.
13.	Dark red clay	145 feet.
		601 feet.

That part of the section below and including No. 6 belongs to the Triassic. From No. 2 to No. 6, which I propose to call the Tucumcari beds, are Cretaceous, while No. 2 is the Tertiary, the same as the upper part of the Staked Plains. I make these distinctions that they may be discussed separately.

In 1852 Professor Jules Marcou visited this locality and made a section of Pyramid mountain, which is substantially the same as that given above. In his section, however, he placed all above the Triassic

in the Jurassic, and by some mistake called the bed above the blue clay, limestone, when in reality it is sandstone. The mistake can be very easily understood by those who are acquainted with the circumstances under which he wrote the *resume* of his work as published in "Geology of North America." His notes had been taken from him, and he had only a private diary from which to make out the report. I am sure the error would have been avoided if he had been permitted to retain his notes until the report was completed.

W. P. Blake, in whose hands Marcou's notes were placed, published the notes in French and his translation of them in parallel columns. (Pacific Railroad Reports, Vol. 3.)

Meek's transalation of the notes on Pyramid Mount, after having given the beds below, including those of clay shale, says of the bed in question: "Then comes a calcareous sandstone, yellow and shining, very hard, with strata five or six feet in thickness, which becomes yellow at the summit." Again, in giving a section of the Staked Plains, and what he calls the second steppe, he says: "This second mesa is entirely formed of blue clay at the base, then yellowish sandstone, and finally the summit is again very compact white siliceous limestone." The only blue clay bed in the vicinity is that in which the fossil zone of the *Gryphæa dilatata*, var. Tucumcari, occurs. So I think it can be seen, even from Marcou's writings, that it was an error to call limestone the calcareous sandstone above the blue clay, and with this exception the section of Pyramid Mount by Marcou is substantially as I found the strata at Tucumcari.

The Tucumcari beds commence about four or five miles east of Fossil creek, where Marcou first mentions having seen the water-worn specimens of the *G. dilatata*, var. Tucumcari. At the place of its first occurrence section No. 18 was made as given in a previous page.

At this place the blue shaly clay was only about twenty feet thick, and the sandstone overlying it was more calcareous than at any other place at which we saw it.

Since Professor Marcou's visit there has been a controversy between him and several other geologists as to the correctness of his determination of two fossils found at this locality, and consequently of his determination of the age of the beds. The two fossils found and determined were a species of *Gryphæa* and an oyster. The *Gryphæa* Marcou described as *G. dilatata*, var. Tucumcari, and the oyster as *O. marshii*, Sow. Those who opposed his opinion contended that the *Gryphæa* was but a species of *G. pitcheri*, Morton, and the other *O. subovata*, Shumard. These geologists never visited the locality, but based their opinions upon Marcou's observations and the specimens collected by him.

No other information had been obtained from this locality until 1888, when Professor Robert T. Hill visited it and confirmed Marcou's

determinations. Professor Hill again visited the locality in April, 1891.

In the prosecution of my work as Geologist for Northern Texas on the State Geological Survey, I found myself within a few miles of the locality, and as it was a matter of interest to science in general, and to Texas geology in particular, I went there and made examinations of the strata constituting the Tucumcari beds and their relation to the surrounding strata. I made a large collection of the invertebrate fossils as well as some of the fossil flora. In order that I may not misstate or give erroneous interpretations to the work and statements of those who have visited the locality before I did, and that they may express themselves in their own language, I will make some extracts from the publications of Marcou and Hill.

Marcou says:*

"The second point where the expedition has quitted the strata of the Trias for a more recent formation, is at the place where we crossed the Llano Estacado (latitude 35°, 17′, 18″, longitude 102°, 53′, 24″). The base of the Llano is formed wholly of the upper strata of the Kueper, which reaches half way up the height of the plateau. These strata, which are of red color, are suddenly replaced by white sandstone, containing numerous calcareous concretions, then by a compact white limestone, sometimes oolitic, that forms the summit of the Llano. These beds are superposed in concordant stratification upon those of the Kueper.

"The Llano Estacado consists of two table lands of different elevations. We crossed the lower one about forty miles further west, near Fossil creek and Tucumcari Mount (latitude 35°, 01′, 16″, longitude 103°, 52′, 29″). There is a second steppe, one hundred and fifty feet higher than the first, also forming a vast mesa, which extends to the Pecos. This second mesa is entirely formed of blue clay at the base, then yellowish sandstone, and finally the summit is again a very compact, white siliceous limestone.

"Obliged to confine myself to a single excursion, I chose an isolated hill on the left of our road, six miles from our camp No. 49, and which we called Pyramid Mount (latitude 35°, 10′, 16″, longitude 103°, 58′), its shape being that of a quadrangular pyramid.

"The north side of Pyramid Mount† is entirely precipitous, perpendicular as a wall, without any particle of vegetation, and showing all the strata; it is impossible to desire a clearer or better geological section. The height of the bluff where the beds outcrop is five hundred feet. I give below the section as I observed it in a short examination of only four hours duration:

G.	White limestone	2 feet.
F.	Yellow limestone	50 feet.
E.	Blue clay	30 feet.
D.	White sandstone	25 feet.
C.	Yellow sandstone	80 feet.
B.	White sandstone	8 feet.
A.	Grayish blue clay	1 foot.

*Geology of North America, p. 17.

†Pyramid Mount is about ten miles southwest of Tucumcari mountain.—W. F. C.

"At the bottom of E. is the zone of the *Gryphæa dilatata*, var. Tucumcari, and the *Ostrea marshii.* From the base half way up, the first two hundred feet are composed of strata of variegated marls, red, green and white, having the same appearance as the upper part of the Kueper in the quarries of Boisset, near Salins, France. A bed of grayish blue clay (A.) one foot thick, forms the last strata of new red sandstone, and is in contact with a white very fine grained sandstone (B.), which is eight feet thick and belongs to the Jurassic formation. Above there is an enormous mass, eighty feet in thickness, of very hard fine grained sandstone (C.) of a light yellow color, and cut by cleavage perfectly perpendicular like a wall. Beds of white sandstone (D.) are superposed; they are very fine, soft and easily disintegrated by the action of the atmosphere; at the foot of each bed little heaps of sand are seen which result from this decomposition; the thickness of the beds is twenty-five feet. Then comes clay (E.) of a slight grayish blue color and sub-schistose structure, thirty feet thick.

"In this blue clay, six inches distant from the white sandstone, I found a zone of *Gryphæa* not more than three inches thick, but the specimens are so abundant that they are in contact with each other. The *Gryphæa* that I had collected at the foot of the bluff and on the ascent, though rolled and worn, had struck me as resembling in shape the *Gryphæa dilatata* of Oxford and the Vaches Noires in Normandy. When I had them in the strata itself, and had collected a hundred in perfect preservation, I no longer doubted their identity with the *Gryphæa dilatata* of the Oxfordian group of England and France. Soon after, in the same zone with the *Gryphæa* I found two specimens of the *Ostrea marshii*, a very characteristic fossil of the lower oolite of England, France and Germany. This discovery of Jurassic fossils proved to me that I had at last met with the true Jurassic rocks in North America.

"To return to Pyramid Mount. Above the fossiliferous blue clay are beds of sandy limestone (F.) of a deep yellow color and very hard; when broken it shines and shows brilliant points, like the yellow limestone of the inferior oolite of the Jura. These beds are each five or six feet thick and rise to the top of the pyramid where the upper strata is a white siliceous and very compact limestone (G) resembling lithologically the Forest Marble (Calcaries de la Citadelle) of the environs of Salins and Besancon."

Prof. R. T. Hill, in discussing the various forms of the *Gryphæa pitcheri*, and in allusion to the controversy about the *G. dilatata*, var. Tucumcari, says:*

"During the month of August, 1888, for the purpose of ascertaining the exact truth of the disputed point, the writer visited Marcou's typical locality of Tucumcari mountains, New Mexico, and found that the *Gryphæa dilatata* occupies a definite horizon, occurring by the thousands, far below what had hitherto been supposed to be the base of the American Cretaceous where the small and entirely different typical variety of *Gryphæa pitcheri*, Morton, usually abounds.

"For thirty years the observations of Mr. Marcou have suffered the disapproval of American geologists on this point, but I am inclined to believe in the correctness of his position. * * * This broad dilate Jurassic *Gryphæa* of Marcou may nevertheless be antecedent of the *Gryphæa pitcheri* of Morton."

In Circular No. 1, issued by Mr. Hill as a University Series from the School of Geology, in referring to the work done since the publication of Bulletin No. 45 of the United States Geological Survey, he says:

* Arkansas Geological Report, 1888, Vol. 2, pp. 172, 173.

"4. The affirmation of the age of Tucumcari section along the northwest corner of Texas to the uppermost Jurassic as originally described by Marcou."

Mr. Hill revisited Tucumcari the second time in April, 1891. After that visit and re-examination of the section, he says: *

"Upon careful comparison I am also inclined to think the upper half of Tucumcari mesa, New Mexico, which I have visited, is composed, below the cap rock, of Trinity sands."

It will be seen from the quotations that they both put the Tucumcari beds in the Jurassic, at least Mr. Hill does after his first visit to the locality. After his second visit he correlates the beds below the cap rock with the Trinity sands, but does not say whether he intends to reaffirm or correct his former reference, for he has never affirmed definitely just where the Trinity sands belong. Sometimes he has put the beds in the Cretaceous, and at other times in the Jurassic, as can be seen by reference to his numerous publications on this subject. On page 125, Vol. 2, of the Arkansas Geological Report, 1888, he says:

"The stratigraphical position beneath the lowest Comanche series, which is of very early Cretaceous (Neocomian), and the extreme difference in the character of the sediments and fossils, confirm the opinion that the rocks are the uppermost Jurassic, lowest Cretaceous (Wældon), or transitional Jura-Cretaceous."

I will first notice the reasons given by these gentlemen for the conclusion that these beds are Jurassic, before giving the reasons I have for placing them in the Washita division of the Cretaceous.

Prof. Marcou bases his conclusions, first, upon the similarity of the lithological character of the rocks to the Jurassic rocks in England, France and Germany; second, upon the stratigraphic position of the beds; third, upon the paleontology.

It must be apparent to even a casual observer that in strata as widely separated geographically as are the beds of Tucumcari, in New Mexico, and those in Europe, their lithological similarity would not be conclusive of their belonging to the same geological age.

Upon the very question at issue Prof. Louis Agassiz says: †

"Whoever has read Marcou's paper on the Jura must have seen that he knows, as well as any geologist living, that lithological characters are of no value in identifying geological horizons, but after presenting the general evidence, as far as it goes, for the presence of Triassic and Oolitic beds in the middle tract of our continent, I cannot find that there is any reason for blame, with his familiarity with the Triassic and Oolitic beds of Europe, in his pointing out the lithological resemblance there may be between them."

The similarity in lithological resemblance between strata in near or adjoining territory would be a very good reason for concluding that the two beds were of the same geological age, and these resemblances

* Bulletin of the Geological Society of America, Vol. 2, p. 506, May 5, 1891.

† Silliman's Journal of Science, Second Series, Vol. XXVII, No. 79, p. 134, January, 1859.

would very readily suggest to one as familiar with the formation in Europe as was Marcou, that they were similar in age, and one would be warranted, in the absence of other facts, in so referring to them, at least provisionally, to the same formation. All I contend for is that this kind of evidence is not conclusive, and especially so in beds so widely separated as are those in Europe and New Mexico.

The stratigraphic position of these beds prove nothing. The position they occupy would go as far to prove they were Cretaceous as that they are Jurassic. They are between the Triassic and Tertiary, and their stratigraphic position could be used as much in favor of one as the other. The fact that they lie in concordant stratification with the Triassic might be used as an argument that there was continuity of sedimentation, and therefore Jurassic; but that does not necessarily follow, for there is often a conformity of stratification between beds of widely different ages. Along some parts of the eastern escarpment of the Staked Plains the well known strata of the Cretaceous lies directly upon the Triassic and is in conformable stratification.

The only remaining reason then to be considered, and it seems to me the only one that need be referred to, is that based upon the fossils found in these beds. There are two species upon which Professor Marcou bases his conclusions, and which he has designated *Gryphæa dilatata*, var. Tucumcari, and *Ostrea marshii*. That the *Gryphæa dilatata*, Sow., and *Ostrea marshii*, Sow., are characteristic of the Jurassic in Europe I am ready to admit. Those who have heretofore opposed Marcou's determination of the beds to be Jurassic have controverted the correctness of his determination of these fossils. As mentioned elsewhere they contended that the *Grpyhæa dilatata*, var. Tucumcari, Marcou, was only a variety of *G. pitcheri*, Morton, and the *Ostrea marshii*, Sow., was *O. subovata*, Shumard.

Since making the collection at Tucumcari I have had the opportunity of examining specimens of *G. dilatata*, Sow., from France and Germany, and have compared the fossils found at Tucumcari with them. There is no doubt that this dilate variety is very similar to that of Europe, and I can say I think Marcou was right in making this fossil a variety of the original type. It is so different in its specific characteristics from the *G. pitcheri*, Morton, that there is very little in common between them.

The other fossil upon which he bases his conclusion, *Ostrea marshii*, I have not been able to determine as positively. I have been unable up to the present writing to get a specimen from Europe for comparison. I have compared the specimens taken from Tucumcari with samples of *Ostrea subovata*, Shumard, taken from several localities in Texas, and they seem to be identical with Shumard's type, and I think they are the same. This fossil is rare in these beds, and is not so well preserved as the *G. dilatata*, var. Tucumcari.

Mr. Hill says:* "There is some reason to believe that it is the same as *O. subovata*, Shumard, which extends from the Travis Peak (Trinity sands) to the Shoal creek limestone." Just what his reasons were for such a conclusion he does not say. Nor does he say whether or not he ever saw a specimen of the fossil from Tucumcari.

Upon the similarity of these fossils with the European species Marcou based his opinion that the strata was the same age as that in which they occur in Europe, and with the evidence then before him, I think he was warranted in his conclusion, yet this is not conclusive of the fact, for the following reasons:

1. It has not been found that fossils of a similar form and species in Europe and America always come from the same series. Fossils that are characteristic of a series in Europe are sometimes only found in a different one in America. It is true that many similar species in both countries have been only found in similar series, and when the fossils are similar it goes very far to prove the similarity of the formation, but it is not conclusive.

2. Until a greater amount of the fossils of a bed are collected and studied, no one is warranted in determining positively the age to which the bed belongs.

The evidence heretofore collected and published was in favor of Marcou's reference to the Jurassic. The main part of the controversy between Marcou and others in relation to the Jurassic at Tucumcari has been based upon the correctness of his determination of the *Gryphœa dilatata*, var. Tucumcari, Marcou. If the question is to be decided by the correctness of his determination, then the fact will have to be admitted of the existence of the Jurassic at that place, for the fossil is not *Gryphœa pitcheri*, but far from it, and is closely allied to the *G. dilatata* of Europe.

What I contend for is that the whole fauna of a group must be considered in order to correctly determine the age of a strata so nearly related as are the Jurassic and Cretaceous, and not upon the close resemblance or even identity of a few species with similar species in widely separated localities. There are exceptions to this point contended for, which will be given when I present the evidence of the Cretaceous age of the Tucumcari beds.

Mr. Hill has attempted to correllate these beds with the Trinity sands, and I suppose he does so upon paleontological evidence, as he says the *Ostrea marshii* of Marcou is probably the same as *Ostrea subovata*, Shumard, "which," he says, "extends from the Travis peak (Trinity sands) to the Shoal creek limestones." There is no evidence that a single specimen of *O. subovata*, Shumard, has ever been found in the Trinity sands. The locality given by Mr. Hill is not in the Trinity sands, but is above the first Caprotina horizon; therefore any

*Bulletin No. 4, Texas Geological Survey, p. 7.

argument that might be based upon the supposed identity of the two fossils would not go to prove the Trinity age of the Tucumcari beds.

The reason for referring the Tucumcari beds to the Washita division of the Cretaceous is based upon the paleontology of the beds. During my explorations in that vicinity I collected a great number of fossils, which are now in the Museum at Austin. While the lithological character and stratigraphical position of beds in certain cases may be very important factors in determining the age of the strata, yet it seems to me, where paleontological evidence can be had, it is by far the most conclusive.

In 1861 Marcou wrote and published "Notes on the Cretaceous and Carboniferous Rocks of Texas," in the proceedings of the Boston Society of Natural History, Vol. VIII, January, 1861. In that article, after reviewing what Dr. Benjamin Shumard had written about Marcou's identification of the fossils found by him at Tucumcari with European Jurassic fossils, he says: "I can only express the wish that when Dr. Shumard goes to Pyramid Mount he may find more fossils than I did, and if any of them are Cretaceous and below the *Gryphœa tucumcari* bed, I am ready to yield to such proof."

I did not find the Cretaceous fossils below the *Gryphœa* beds, but I found them in the beds, associated with the fossils found and described by Marcou. I believe if Marcou had seen the fossils I have collected he would not have hesitated to place the Tucumcari beds in the Cretaceous.

The following is a list of the fossils collected by me from the Tucumcari beds in the vicinity of Tucumcari and Pyramid mountains:

Gryphœa dilatata, var. Tucumcari, Marcou.
Ostrea marshii, as determined by Marcou.
Gryphœa pitcheri, Morton.
Exogyra texana, Roemer.
Ostrea quadriplicata, Shumard.
Trigonia emoryi, Con.
Cardium hillanum, Sow.
Cytherea leonensis, Con.
Turritella seriatim granulata, Roem.
Pinna, sp.
Ammonites.
Pecten.

These fossils at once show the age of the strata from which they were taken, leaving out of consideration for the present the first two in the list.

The *Exogyra texana*, Roem., is found only in the Cretaceous, extending from the base of the Fredericksburg division into the Washita division. Neither it or its congener in Europe has ever been reported from the Jurassic.

Ostrea quadriplicata, Shumard, is very numerous in the Washita division of the Cretaceous, and has never been found elsewhere. The *O. crenulinaryo*, Roemer, which is a very similar though specifically distinct form, comes from a lower division.

Trigonia emoryi, Conrad, has been found in the Washita division of the Cretaceous.

Cardium hillanum, Sowerby. This fossil has been reported from the Washita division.

Cytheria leonensis, Conrad, is a Cretaceous fossil found only in the Washita division.

Turritella seriatim-granulata, Roem., is a Cretaceous fossil described from the Fredericksburg division.

Gryphœa pitcheri, Morton, ranges from the middle of the Fredericksburg division to the top of the Washita division. This fossil is so different from the *G. dilatata*, var. Tucumcari, Mar., that notwithstanding they are found in the same bed, there was not the slightest difficulty in distinguishing one from the other.

The only representative of the fossil flora we found was in the sandstone above the bed of blue clay, bed "F" of Marcou's section. A figure and description of one of the leaves is given at another place.

This single specimen, taken from these beds, even if there was no other, is sufficient to establish the fact that the strata are no older than the Cretaceous. It is true that, as a general thing, the whole of a flora or fauna of a strata ought to be examined before one can say definitely the age to which the strata belong, yet there are cases where the sub-divisions may be definitely determined by a single specimen. This matter is so clearly stated by Lester F. Ward in a late paper that I quote the following extract:

"The great types of vegetatation are characteristic of the great epochs in geology. This principle is applicable in comparing deposits of widely different ages where the stratigraphy is indecisive. For example, in rocks that are wholly unknown even a small fragment of a carboniferous plant proves conclusively that they must be paleozoic, or a single dicotyledonous leaf that they must be as late as the Cretaceous."*

While the Jurassic and Cretaceous are not widely separated, and both are in the Mesozoic, yet some of the plants are so widely different that a single specimen would be sufficient to determine that the age was no earlier than the Cretaceous.

It is a conceded fact that the beginning of the Cretaceous period was the first of the plants classed as angiosperms, and that prior to that time not a single specimen, of what was afterwards an abundant flora, has been found.

*Science, November 30, 1891, p. 282.

The following statement has been found correct in relation to the flora of the Cretaceous:

"The Cycads of the Triassic and Jurassic still existed, but they were accompanied by the first yet known of the great modern group of angiosperms—the class which includes the oak, maple, willow and the ordinary fruit trees of the temporate regions, in fact all plants that have a bark excepting the conifers and cycads."*

That this plant figured belongs to the class which had its beginning in the Cretaceous seems to me beyond question, and with the evidence of the invertebrate fossils establishes beyond controversy the Cretaceous age of the Tucumcari beds.

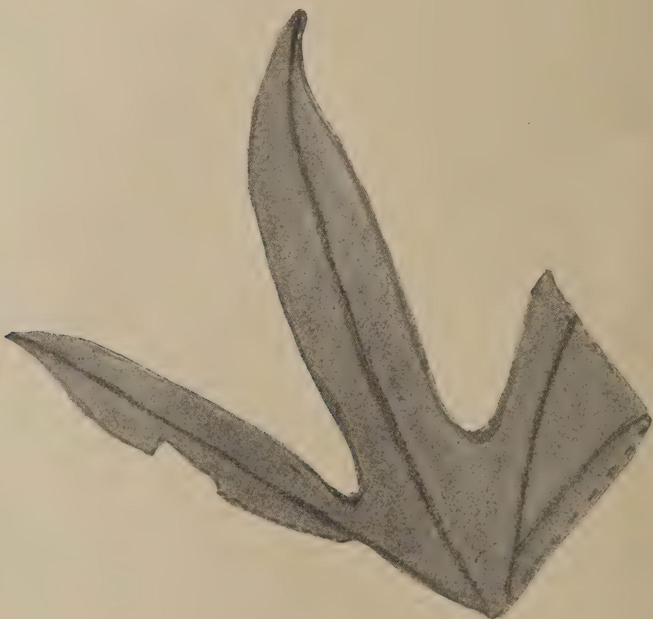


Figure 8.

STERCULIA DRAKEI, SP. NOV.

Palmately three lobed, lobes unequal, medial lobe longer, acute at apex, nervation indistinct, base of leaf not seen.

LOCALITY.

Upper sandstone of the Tucumcari beds, four miles west of Big Tucumcari mountain, New Mexico.

The only leaf of this species collected is well preserved in outline. It is 90 mm. broad between the points of lateral lobes, which diverge at an angle of 30 degrees. The center lobe is 90 mm. long above the point of divergence of the other two lobes. The lateral lobes are 70 mm. long.

*Dana's Manual of Geology, p. 458.

VALLEY OF THE PECOS.

The territory embraced under this heading is the district of country situated between the western escarpment of the Staked Plains and the Guadalupe mountains on the west. This district might, with propriety, be called the valley of the Pecos river, concerning which very little has heretofore been written and published by any one. It seems to have been out of the line generally traveled by geological explorers, at least in recent years. From a point opposite the most northwestern extension of the Staked Plains to the northern line of Texas, a distance of two hundred and twenty-five miles, and between the western escarpment of the Plains and the mountains there has never been a report made of the geology, so far as I am informed. During the years from 1852 to 1855 various parties crossed the lower part of this district, and the reports made at that time contain much valuable information, yet the explorations were made under so many disadvantages that it is a matter of surprise that the reports do not contain more errors than are really to be found in them.

One of the questions to be studied by me during the past year's field work rendered it necessary to study the geology of the country between the western edge of Texas and the mountains on the west, and for that purpose I made a trip the whole length of the district from Tucumcari Mount to Horsehead crossing on the Pecos river. In this district the Carboniferous, Permian, Triassic, Cretaceous and Tertiary formations occur, each of which will be given a brief description in the order in which they are mentioned.

CARBONIFEROUS.

The Carboniferous formation is found only in the higher mountain range and foot hills along the western border of the district. The thickest part observed, about two thousand feet, is on the south, probably only because it is more exposed by upheaval and erosion in that direction than any other. It is no doubt much thicker. The strata are composed of massive layers of sandstones, limestones and shales. The dip is generally to the southeast, at a high angle in the mountains, but much less in the foot hills, and at places the beds are almost horizontal. There are localities where folds in the strata run at, or nearly at, right angles with the mountain range, making troughs in which the newer formations occur.

The fossils found would indicate that the horizon is about the middle of the Carboniferous formation, as seen on the eastern side of the Plains.

In the mountains there is a massive white limestone, first described by Dr. Shumard, in 1855, and supposed by him to be Permian, but none of the characteristic fossils were found in it, and its lithological characteristics are very different from the Permian which occur in the

valley below and in the area east of the Staked Plains, where it is so largely exposed. The strata are entirely barren of coal. The conditions necessary to the accumulation of vegetable material seem to have been entirely wanting during the deposition of the beds. I do not know of a single instance in which even a thin seam of coal has been found anywhere in the Coal Measures of West Texas.

Just what amount of water the formation carries has never been ascertained, but it is known that some of the beds are water-bearing. At the head of Delaware creek a spring issues from a fissure in the Carboniferous rocks, highly impregnated with sulphur, and emitting sulphureted hydrogen in such quantities as to be smelled for some distance around the place. The same water was reached at a depth of eight hundred and thirty-two feet at Toyah, where it flows from the well in considerable quantities.

Aside from these two places I do not know of a locality where water has been found in the Carboniferous strata in this part of the State. The probable reason of this is that the strata dip to the southeast, and only a short distance from the mountain range are overlaid by newer formations, and none of the wells put down have ever reached it.

PERMIAN.

The Permian formation was first seen in the vicinity of old Fort Sumner, and is continuous in the valley of the Pecos river entirely through the district under consideration. The strata are composed of sandstones, limestones, gypsum, and beds of red and blue clay.

The whole of this formation was placed by Dr. Shumard in the Cretaceous under the name of Marly Clay. He did the same with the Red beds on the eastern side of the Staked Plains. He recognized the formation on both sides of the Plains as being the same, as they really are. He found no fossils during either of his trips up Red River, but determined the age by the stratigraphy alone. We found no fossils in the beds west of the Plains, but as we had traced the formation on both the eastern and northern sides, there was no doubt as to its being the same when we found it on the west. We made the determination on lithological grounds as well as stratigraphical relations.

The strata lie unconformably on the Carboniferous, dipping at a smaller angle to the southeast. The sandstones are much softer and more shaly than those of the Carboniferous, though there are places where they are very compact.

The magnesian limestones have much the same characteristics as those east of the Plains. They have been badly fractured by the later upheavals and disturbances of the strata.

The gypsum lies in thick massive beds in the red clays, ranging in color from the snow white alabaster to the more coarse and earthy varieties. All the beds of red clay are more or less interstratified with

thin seams of gypsum, and by seams of fibrous gypsum and selenite traversing and cutting the beds in every direction.

The beds of clay are generally red, and range in thickness from a foot to one hundred feet or more. All of them are more or less impregnated with salts of different kinds, principally chloride of sodium.

The Pecos river has cut a broad valley and channel through the newer and overlying beds and into this formation, but at no place did I see the strata of the lower rocks exposed. It is probable that the dip of the Carboniferous puts it much below the bed of the river. The thickness of the Permian beds on the west side of the Plains has not been determined.

The heavy beds of gypsum end in a bold escarpment running parallel with the Guadalupe mountains, near their southern extremity, and at a distance of five or six miles. All the water from these beds, or which runs across them, is more or less impregnated with salts, and is generally known as gypsum water. From the vicinity of old Fort Sumner to Roswell, a distance of seventy-five miles, all the water is of this sort. There are numerous extensive areas where the quantity of alkali is so great that no vegetation can grow. Ten miles north of Roswell we passed a salt flat two or three miles in extent, and salt marshes were numerous.

There is no artesian water in this formation, there being no stratum sufficiently porous to be water-bearing. The sandstones are generally cross-bedded, or so filled with clay that water could not readily pass through them, and notwithstanding the fact that the Pecos river has cut deeply across the strata of this formation, there are very few springs found issuing from it. Had there been much water in any of these beds there would have been numerous large springs on the west side, as the strata dip toward the river from the west and are cut in two by it.

Any water that might be found in the Permian strata by deep boring would be so highly impregnated with salts as to be unfit for ordinary use. It would, however, be possible, anywhere west of the Staked Plains, to bore through the Permian and reach the water of the Carboniferous at less than two thousand feet.

TRIASSIC.

This formation underlies the Tertiary along the western border of the Staked Plains, and at old Fort Sumner, on the Pecos river, rests directly upon the Permian. South of Fort Sumner, on the west side of the river, the Tertiary, where seen, overlies the Permian, the Triassic having been eroded before the deposition of the Tertiary. The details are given in a separate paper by my assistant, Mr. N. F. Drake.

CRETACEOUS.

The Cretaceous formation was seen north of the Davis mountains along the line of the Texas and Pacific Railroad, at Kent and other places to the westward, in a range of hills along the northern foot, extending nearly to the southern end of the Guadalupe mountains.

The highest beds seen were the Arietina clays. The general dip is to the eastward. The formation does not seem to have been disturbed by the mountain upheavals, and was probably deposited since there has been any considerable elevation of the older strata. The whole formation has been subjected to heavy erosion. Some of the hills are three hundred feet high, and the drift from the destruction of the strata is strewn all over the valley of the Pecos.

The following is a section made at Kent:

1. Alternating thin layers of friable limestone and calcareous clays, the clay being in thin layers and containing fragments of limestone. This bed contains *Ostrea diluviana*, *Pecten texanus* (?) and *Toxaster texana* . . . . 20 feet.
2. Massive limestone three feet thick, alternating with layers of white limestone and thin beds of clay. The massive layers weather uniformly and would make good building stone. The upper layer contains a great number of the young of the *Exogyra arietina* . 30 feet.
3. Alternating layers of argillaceous limestone and clay. The limestone breaks on weathering into large pieces. It is slightly yellowish white. Twenty-five feet of the base of this bed has a great many *Echinodermata*, a few ammonites, large gasteropods, *Nautilus*, and *Terebratula wacoensis* . . . . 240 feet.
4. Alternating layers of limestone and clay, the limestone readily crumbling into small pieces with rounded surfaces or edges. It contains small *Gryphœa pitcheri*, *Toxaster texana*, ammonites and *Cyprimeria* . . . . 40 feet.
5. Shaly blue clay having three thin layers of brittle yellow limestone. The upper layer near the top of bed contains *Ostrea quadriplicata*, Shumard. The center layers contain a large number of ammonites, and a few *Gryphœa pitcheri* and *Cyprimeria*. The bottom layer has ammonites and *Gryphœa pitcheri* . . . . 30 feet.

Below this section, in a well, is calcareous yellow sandstone for thirty feet, resting on blue shale. From the fossils I conclude that the strata belong at the top of the Washita division of the Cretaceous.

Dr. Shumard reported having seen the Cretaceous strata near the mouth of the Delaware on the Pecos, but I passed over the same place and saw only the Permian. It must be borne in mind that he put the whole of the Permian in the Cretaceous, both on the eastern and western side of the Staked Plains, and what he called Cretaceous here has since been determined to be Permian, as well as that on the eastern side of the Staked Plains. It may have been that the Cretaceous strata covered much of the country now embraced in the eroded district east of the Guadalupe mountains, but there is now no part left on any of

the area in proof that such was the case. No part of the Cretaceous was seen after leaving Tucumcari until near the southern part of the Guadalupe mountains, a distance of about two hundred and seventy-five miles in a direct line. The Tucumcari beds are probably the same as those occurring south of the Guadalupe mountains in the vicinity of Kent.

The Cretaceous generally contains good water-bearing beds, but no water has been found in the formation west of the Pecos river and north of the Davis mountains; the cause of this is no doubt owing to the destruction of the strata by erosion, the strata being now merely fragmentary, and cut across at many places.

The Cretaceous everywhere in the district rests directly upon the Triassic wherever I have seen the contact. At other places in the west I have seen it directly in contact with the Carboniferous.

TERTIARY.

The Tertiary lies directly upon the Cretaceous at Tucumcari, and the whole distance from Tucumcari to the line of the Texas and Pacific Railroad, west of the Staked Plains, it rests directly upon the Triassic. On the western side of the Pecos river, at various places, there are patches of the Tertiary lying in troughs in the older strata, and may at one time have extended over the entire area from the foot of the mountains to the western boundary of the Staked Plains. In fact it is evident that the remnants of the Tertiary found on the western side of the Pecos river are a part of the Staked Plains, and that which once existed in the intermediate space has been destroyed by erosion.

Southward from Roswell, in New Mexico, to the mouth of Seven Rivers, there are broad level plateaus with a slight dip to the southeast. At numerous places are outcrops of a white chalky limestone that very much resembles the upper bed of the Tertiary on the Staked Plains. It is probable that the source of the water in the big springs near Roswell is in the base of the Tertiary. As soon as the water from the mountains on the west reaches the foothills it sinks at once into the Quarternary drift, and then no doubt passes to the base of the Tertiary, and when it reaches the point where the stratum has been cut by erosion, it breaks out in the large springs mentioned.

There were valleys of erosion at places in the older strata before the deposition of the Tertiary, and when that occurs the water collects in narrow streams and finally rushes out in springs of large size, such as the springs at the head of North and South Spring creek, in the vicinity of Roswell.

No Tertiary was seen south of the mouth of Seven Rivers, on the west side of the Pecos river. A great deal of the country between the north line of Texas and the Davis mountains on the south is so deeply covered with Recent drift that if any part of the Tertiary remains in that region it is hidden under this drift.

ECONOMIC GEOLOGY.

IRRIGATION IN THE PECOS VALLEY.

The area intended to be embraced under the above caption is the district already described, between the western escarpment of the Staked Plains and the foot of the mountain range on the west.

The Pecos river rises in the mountains one hundred miles northwest of Las Vegas, New Mexico, and runs through the district under consideration from northwest to southeast.

After emerging from the foot hills the broad plains on each side of it stretch away in every direction as far as the eye can reach. These broad plateaus can be reached by the waters of the Pecos river and its tributaries, by systems of irrigating canals which have been already inaugurated. This valley is within the arid belt; that is, in the area in which there is insufficient rainfall to mature the crops, and all agricultural pursuits are dependent upon irrigation, but there is no district in that belt so well supplied with water as the Pecos valley. Not only does the river run through the entire district with its never failing stream fed by the snows of the mountains about its source, and the numerous mountain streams, but there are numerous other streams flowing into it from the western side, and along the valley are many large springs whose waters give a constant supply.

The water of the Pecos river is clear and pure when it issues from the mountains, but soon after reaching the foot hills it becomes impregnated with salt from the Permian clays, and when it reaches the water of the large springs in the vicinity of Roswell it is more highly charged with these salts than at any other place along its entire course. At Roswell and below, as far as the Texas State line, there are many large streams of fresh clear water running into the river, and these so dilute the water of the Pecos that no damage is to be apprehended from its use below that point for irrigating, even if it should be unfit for it above, which I do not think, for it has been so used above the confluence of these fresh water streams without any deleterious results.

At old Fort Sumner, while the United States troops were stationed there, several hundred acres were under cultivation, irrigated with water from the Pecos river. About the time of the abandonment of the Fort by the troops, in 1870, the dam across the river washed out, and there has never been enterprise or capital enough to rebuild it and the irrigating scheme at that place has been given up. The only evidence now existing of the former enterprise is the old irrigation ditch and the long line of cottonwood trees planted at that time growing along the margin of the old canal and on each side of a broad roadway north of the old fort.

The water of the streams emptying into the Pecos river in the vicinity of Roswell has been used for irrigation for several years, but in a com-

paratively small way, a part only of the water being taken up. Recently, however, more extensive operations have been undertaken. The system now inaugurated will make it possible to bring under cultivation about four hundred thousand acres of land in the Pecos valley between Roswell, New Mexico, and the southern line of Ward county, Texas. The following is a brief statement of some of these enterprises:

THE PECOS IMPROVEMENT AND IRRIGATION COMPANY.

This company has two main canals in the Pecos valley in New Mexico. The northern canal takes its water from the Hondo river, about five miles east of Roswell, and one hundred and fifteen miles north of the Texas State line. This canal extends along and nearly parallel with the Pecos river. At the time of my first visit, in August, 1891, it was completed to the Felix river, a distance of twenty-five miles. It will be extended to Seven Rivers, making in all a length of fifty miles. This canal is thirty feet wide at the bottom and will carry five feet of water. It is thought that the water thus taken out, together with that obtained by storing the flood waters, will be sufficient to irrigate about one hundred thousand acres of land.

About six miles north of Eddy a dam has been constructed across the Pecos river, in a most skillful manner. It is built of limestone rock laid in cement, is forty feet high and one thousand one hundred and forty long. The lake formed by this dam is seven miles long and one and three fourths miles wide, and holds one billion (1,000,000,000) cubic feet of water, enough to supply the ditch with a full head for nearly one month. The main canal leading from the dam is forty-five feet at the bottom and will carry seven feet of water.

Four miles below the dam the water is divided into two smaller canals, one of which is flumed across the river and goes down the stream on the west side; this canal is completed to Black river, a distance of about twenty-five miles. The other goes down the the river on the eastern side; its total length will be about twenty-five miles, and will bring under cultivation about fifty thousand acres of land.

Very little, comparatively, of the lands covered by these canals have been put under irrigation. Where they have been cultivated the production of crops has met the most saguine expectations.

HAGERMAN CANAL.

The water for this canal will be taken out of the Pecos river about fifteen miles below the town of Eddy. It has not yet been completed. Along its course will be a large storage reservoir, one and a half miles long and one mile wide, with an average depth of twenty-five feet. The water will be taken out on the eastern side of the river, but will be flumed across between Black river and Delaware creek, and continued to the Texas State line.

TEXAS LAND AND WATER COMPANY.

About thirty miles below the point on the Pecos river where the line between Texas and New Mexico crosses, the Texas Land and Water Company is building a dam for the purpose of irrigating the lands on the western side. The dam is built of material found in the vicinity and of limestone brought down by the Pecos Valley Railroad from Red Bluff. The canal will extend southward to Toyah creek, south of the Texas and Pacific Railroad, a distance of about forty-two miles. It will be thirty feet wide at the bottom, and will carry six feet of water. By this canal there will be brought under irrigation about seventy thousand acres. There will be reservoirs at convenient localities along the line, wherein the storm water can be stored, which will add largely to the capacity of the works.

PIONEER CANAL COMPANY.

The head of the canal of the Pioneer Canal Company, whose headquarters are at Pecos City, in Reeves county, is about eight miles north of Pecos City. At that place there is a natural dam or falls in the river, which obviated the necessity and expense of constructing an artificial dam to force the water into the canal. They simply cut their canal and put in a head-gate, so as to take out just such quantity of water as may be found necessary or desirable. The water is taken out on the west side of the river, and the canal is already constructed to a distance of seventeen miles, and will bring under irrigation about thirteen thousand acres of land.

This company is now constructing a canal on the eastern side of the river also, which will be thirty-five miles long, and will irrigate about seventy thousand acres of land. The water will be flumed across the river five miles north of the town of Pecos.

SOILS AND WATERS OF THE PECOS VALLEY.

There are three different classes of soil in the Pecos valley with their intermediate grades. The first is a reddish adobe soil, composed of the later river deposit. The second is a sandy loam and is an admixture of the soils of the first class and the sand from the higher elevations. The third class is a sandy soil and has been made principally from the detritus from the surrounding and adjacent hills.

The first and second classes of these soils are more or less impregnated with salts in the form of chlorides as will be seen at another place in this report. That a certain percentage of these salts are beneficial to plant growth is well known, but where they are in excess they become deleterious to plant life. That the soils of the Pecos do not contain these salts in excess is shown by the vigorous growth on them and the large yield in the crops where they have been cultivated.

In the valley of the Nile in Egypt the most fertile soil has as much as three per cent of common salt, and yet they raise abundant harvests every year.

There are places, however, in the Pecos valley where there is an excess of these salts and where no vegetation except salt grass will grow. These places are known as alkali spots. Even they are made capable of producing excellent crops by washing out the surplus salts.

These spots vary in size from a few feet in diameter to several acres. By analysis they are found to contain lime, soda and potash. The soda is present as chloride, sulphate and carbonate. Wherever these alkali spots occur it has been found that the highest percentage of the salts was at the top or on the surface, sometimes forming incrustation. The cause of this is probably that when the water is taken up from the surface by evaporation, leaving the salts behind, other water comes up from the subsoil charged with salts, which in turn is evaporated, and so the process goes on from year to year, and as the rainfall and drainage is not sufficient to carry off the surplus salt deposit it is left on the land.

It has been found practicable to redeem these spots and make them as productive as the other lands. To accomplish this, various plans have been adopted. The best way is to flood the land and let the water carry off the salts where water in sufficient quantities can be had. It has been found that the planting of certain crops on the land would greatly diminish the amount of alkali. Beets and sorghum grown on the land will do it very rapidly.

Care must be taken in irrigating with Pecos water that the amount of alkali in the soil be not increased rather than diminished, for all the water in the Pecos river is more or less charged with alkali. This can be avoided by flooding the land occasionally and letting the surplus water flow back into the original ditch or river.

That there are more salts in the lands after they have been irrigated three years than in the virgin soil, is shown by the analyses of the soils collected by myself from the experimental farm of the Pioneer Canal Company and analyzed by Mr. L. E. Magnenat, chemist of the Survey, but whether the increase of the salts was by successive deposits or from that of the last irrigation cannot now be determined. The following statement is taken from Supplement to Bulletin No. 2, relating to this matter:

Soil No. 1. Virgin soil from section 174, block 34, H. & T. C. Ry. Co.
Soil No. 2. Unirrigated, experimental farm.
Soil No. 2a. Irrigated soil, experimental farm.
Soil No. 3. Unirrigated soil, experimental farm.
Soil No. 3a. Irrigated soil, experimental farm.

	Total water Soluble.	Sodium Chloride.
Soil No. 1	0.16 per cent.	0.046 per cent.
Soil No. 2	0.23 per cent.	0.044 per cent.
Soil No. 2a	0.38 per cent.	0.074 per cent.
Soil No. 3	0.48 per cent.	0.092 per cent.
Soil No. 3a	1.26 per cent.	0.164 per cent

While this is true, however, the total amount of sodium chloride which is present in the soil is so small, and the annual addition from the water used in irrigation is so little, that it will require many years cultivation to bring the total amount into anything like a dangerous quantity. Thus, in soil No. 2 and 2a, the increase is only ten thousandths of one per cent annually, and even in the one showing the largest increase, No. 3 and 3a, the difference is only twenty-four thousandths of one per cent, at which rate it would require nearly forty years to bring the total up to even one per cent of the entire soil, an amount which in itself is far below an excess.

Having ascertained this fact by analysis, it then remained to determine the combination in which the large amounts of alkalies, which we have previously found in the soils, existed.

The water soluble matter was first analysed. Solution was effected by heating with water for five days over a water bath and the alkalies determined in the filtrate. The results are as follows:

	No. 1.	No. 5.	No. 6.
Potassium	0.024	0.07	Trace.
Sodium	0.220	0.25	0.11
Sulphuric acid	0.500	0.60	Trace.
Carbonic acid	Trace.	Trace.	Trace.
Chlorine	0.27	0.10	Trace.

In the water soluble material, therefore, the alkalies are present as sulphates and chlorides, with traces of sodium carbonate.

The total amounts of alkalies present were then determined in fresh portions by the method of Professor L. Smith, with carbonate of lime and sal ammoniac, with the following results:

	No. 1.	No. 5.	No. 6.
Sodium	3.23	4.32	4.11
Potassium	2.61	2.77	1.58
Total	5.84	7.09	5.69

Taking into consideration the amounts of sulphuric acid, carbonic acid and chlorine present, as shown in the analyses, it is evident that the larger portion of the alkalies must exist as silicates, since there is nothing else for them to combine with. This is rendered the more certain by the consideration that the rock material from which the soils are derived is largely feldspathic in its nature, consisting of the intrusive porphyries which cover such an amount of the area west and north of that locality.

With this explanation, the apparent excess of alkalies is shown to be in no wise dangerous to the agricultural prospects of the valley.

Too much attention cannot be given to the manner of irrigation, in order to preserve the present fertile condition of the soil.

The water of the Pecos river, as seen from the analyses, carries salt, which if not removed by flooding or drainage will in time so impreg-

nate the soils that they will lose their present fertility. There must always be sufficient drainage to prevent this accumulation of the salts. As long as there is any water these salts will be held in solution, and it is only from the last evaporation that the salts are precipitated. If, therefore, there are drainage ditches made and kept open so that the last of the water is carried off into the river, no evil results will occur.

The result of this want of drainage can be seen in localities on the Rio Grande. There are places along that river, where for lack of drainage, the land has become so saturated with alkali as to render it absolutely worthless for agricultural purposes, and had to be abandoned. Yet in the same vicinity where the land was so situated that it could be occasionally flooded, it has retained its original fertility, although under cultivation for a great number of years.

Irrigation has been carried on along the Nile in Egypt from time immemorial. There are places along the upper Nile where the cultivation of certain crops has long since been abandoned because of the large amount of salts deposited from the water. But this is only the case where there was very poor drainage, or none at all, and where all the water turned on the land was taken up by evaporation.

In the center of the delta of the Nile, very often the soil contains as high as four per cent of chloride of sodium, yet no deleterious results have accrued. The land is flooded every year and the drainage is sufficient to carry off the surplus water, and with it goes the excess of salts that may have been deposited from the previous irrigations.

ARTESIAN WELLS.

Another source of water in the country west of the Staked Plains will be that of artesian wells. Just how abundant that supply will be has not yet been determined. That the artesian water district will be very extensive there is not much hope, and the area will be confined to the country east of the mountain range. Very little effort has been made to determine the matter, and at only a few places have borings been made.

At Roswell, in New Mexico, water has been found in wells of one hundred and sixty to two hundred feet deep, which yield a small flow of water. The probabilities are that the source is the base of the Tertiary.

At Toyah there is a flowing well which yields three hundred gallons per minute. The water was found at the depth of eight hundred and thirty-four feet, and is impregnated with sulphur and common salt. It has been used in a small way for irrigation, and is suitable for such purposes, as the vegetation does not seem to be injured by its use.

This is the only place where this bed of artesian water has been reached, and no effort has been made to determine the extent of the basin. The water is found in the Carboniferous strata, and as that

formation is quite extensive towards the east and has a dip in that direction, it is more than probable that water can be had as far east as the western escarpment of the Staked Plains.

The elevation of Toyah is two thousand nine hundred and seventy-five feet above the sea level, while the Pecos river, which is about twenty-five miles to the eastward, is two thousand six hundred feet, a difference of three hundred and seventy-five feet. Nothing is known positively as to the rate of the dip of the strata of the Carboniferous in this part of the State, but it is not probable that it is very great after getting away from the mountains. With the difference of elevation between Toyah and Pecos, and in favor of the latter, it is highly probable that the same stratum of water can be found at Pecos as at Toyah at a depth of less than twelve hundred feet, and that it will flow from the surface under good pressure.

There are twenty-three flowing wells at Pecos City within an area of two miles, ranging in depth from one hundred and eighty-five to three hundred and fifteen feet. The wells are three inches in diameter and have a flow of sixty gallons to the minute, or eighty-six thousand four hundred gallons per hour. That amount of water would irrigate one acre of land with three inches of water per day.

These wells cost from three hundred to five hundred dollars each. The water in them is slightly brackish, but pleasant to the taste. It has been used in some instances to irrigate small pieces of land for vegetables and fruits, the only products for which the water has been used, and they grow most luxuriantly.

The extent of this artesian area has not been tested, but I am inclined to the opinion that it is not very extensive. I think it is, however, only one of several such areas along the eastern side of the mountain range. There are troughs in the folds of the strata running at right angles with the mountain range, which are filled with the newer formations, and all of them are water-bearing, and most of them will be artesian basins.

The strata are so covered up at Pecos City by the drift from the breaking down of the Cretaceous rocks, that the geological age of the water-bearing stratum cannot be definitely determined. The strata passed through in boring these wells are different at each well.

The following is a section of the strata passed through in boring the Cox well in the town of Pecos, the depth of which is two hundred and fifty-five feet:

1.	Soil	1 foot.
2.	White clay	20 feet.
3.	Quicksand	2 feet.
4.	Soft sandstone	47 feet.
5.	Stiff yellow clay	20 feet.
6.	Quicksand	10 feet.

7.	White and blue clay	20 feet.
8.	Cavern	5 feet.
9.	White sand	5 feet.
10.	Brownish clay	120 feet.
11.	Sand and gravel	5 feet.
		255 feet.

The wells one and a half miles north of the town are only one hundred and eighty-five feet deep. The water-bearing stratum seems to dip very rapidly to the southward, as none of them in the south part of the town are less than two hundred and fifty feet deep, while the surface of the ground has a dip of only a few feet to the mile. The temperature in the well farthest to the south is seventy degrees. The pressure in some of the wells is sufficient to force the water thirty-five feet above the surface.

Captain Pope's Wells.—In 1855 Captain John Pope, of the United States Topographical Engineers, attempted to bore an artesian well fifteen miles east of the Pecos river, at the mouth of Delaware creek. At the depth of three hundred and sixty feet water was reached, which arose seventy feet in the well and remained at that height. At the depth of six hundred and forty feet a second supply of water was obtained. This water rose three hundred and ninety feet, when the red clay caved in and completely cut off the water, and after several days labor it was found impossible to remove the material that had caved in.

They then went five miles east of the previous location and attempted to bore another well. At a depth of two hundred and forty-five feet the first water was reached, which rose twenty-five feet and remained at that level. At a depth of six hundred and seventy-six feet another stratum of water-bearing sandstone was reached. The water rose to within one hundred and ten feet of the surface. The boring was continued to a depth of eight hundred and sixty-one feet without reaching any other water. The work was discontinued.

The details of the work show that the last water found was below a blue shale, which is no doubt the Carboniferous, and the water was in all probability the same as that of the flowing well now at Toyah.

A detailed statement of this work is given in a report made by Captain Humphries to the Secretary of War, in Supplement to Volume 7, Pacific Railroad Reports, page 31.

STRATIGRAPHY

OF THE

TRIASSIC FORMATION

OF

NORTHWEST TEXAS.

BY

N. F. DRAKE.

STRATIGRAPHY

OF THE

TRIASSIC FORMATION OF NORTHWEST TEXAS.

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The Triassic formation was examined in the vicinity of Dockum, Dickens county, by Professor W. F. Cummins, in 1889, and by him described, under the name of Dockum beds, in the First Annual Report of the Texas Geological Survey.* In the Second Annual Repórt of the Survey† he gave a more extended description of these beds, and stated the published conclusions of other geologists concerning the formation in Texas, drawn from previous observations.

I first saw this formation at Dockum, in company with Professor Cummins, in 1889, being attached to his party as assistant; but nearly all of the present report is the result of observations made by myself in Texas and New Mexico during the past field season.

The Dockum beds underlie all, or nearly all, of the Staked Plains of Texas and southeastern New Mexico, extend further back into New Mexico northwest of the Plains, and have some extension under the Cretaceous area south of them in Texas.

The limit of the Plains on the east, north and west is marked by an escarpment which is usually from one to two hundred, and sometimes three or four hundred feet high. The basal portion, sometimes nearly all of this escarpment, is composed of the Triassic beds. These beds usually extend six or seven miles from the base of the escarpment and nearly surround the plains by a narrow band, as is shown on the map, Plate IV.

As is there shown, this belt extends through Iatan, Mitchell county; Gail, Borden county; Dockum and Espuela, Dickens county; Goodnight, Armstrong county; three miles north of Amarillo, Potter county; centre of Oldham county; Liberty, New Mexico, and with some breaks down the east side of the Pecos river to Castle Mountains, Crane county. The formation spreads out to a considerable width in the vicinity of Liberty, New Mexico, and west of the Pecos river opposite Fort Sumner.

TOPOGRAPHICAL FEATURES.

The nearly horizontal strata of sandstone, conglomerate and clay, varying in thickness and resistance to erosion, have been carved into by branches, ravines and creeks, leaving a rolling landscape. The reg-

* Pages 189, 190.

† Pages 424–428.

ular undulating nature of the beds is occasionally interrupted by more or less precipitous outcrops of sandstone or conglomerate strata. These rocks, resisting erosion longer than the others, often remain capping some point or ridge, walling in the narrow valley of some creek, or forming the channel walls of some ravine or branch. These sandstones or conglomerates are, however, rather soft, and their outcrops are not usually conspicuous away from the rapidly carving action of the streams, but give a rolling character to the surface by slightly holding in check the wear of points here and there, while the intervening softer rocks are worn deeper and deeper.

The topography of the Triassic beds is undoubtedly affected to some extent by irregularities in the erosion of the overlying Tertiary beds. This erosion first marking the places that are afterwards worn down into drainage courses or left as dividing ridges.

Going back from the foot of the Plains to where the Dockum beds disappear, the rolling nature of the country grows somewhat less and in some places is quite level.

LITHOLOGICAL CHARACTERISTICS.

Sandstones, conglomerates, and clays constitute nearly all of the strata of this formation.

The materials composing the different strata vary somewhat in lithological characteristics at different localities, and even at the same locality, but the general characteristics are quite uniform, and are so different from the underlying Permian and overlying Cretaceous or Tertiary, that they are usually easily recognized. This is especially true of the sandstones and conglomerates.

SANDSTONES.

The sandstones before exposure to weather are generally nearly white, but sometimes gray, red, or bluish in color. Massive, shaly, and false bedding are common. The texture varies from a fine, even-grained, to a grit or conglomeritic sandstone. White and a few brown mica flakes, varying in size from a mere speck to one-eighth of an inch in diameter, are nearly always present. This mica is so abundant in some of the rocks as to make them fissile. The sandstones are usually friable, but weather with a smooth flat surface and with an average sharpness of angle for sandstone rocks.

CONGLOMERATES.

The conglomerates are of two kinds. The one most characteristic and widespread is composed of small pieces of brownish, yellowish or bluish colored, sub-angular, indurated, clayey sandstone fragments, averaging about the size of a pea, imbedded in a matrix of sand or

grit usually calcareous. The other is composed of siliceous pebbles in a matrix of sand and grit. The pebbles are usually small and well rounded, and of nearly all shades of color, but white quartz are the most numerous. The quantity of siliceous pebbles varies at different localities from more than half the rock mass to very few. Both conglomerates contain silicified wood at some localities. The bedding of the siliceous conglomerate is unusually even and regular or slightly false, while that of the first named is false almost without exception. These two conglomerates graduate into each other, and even where one is the most characteristic the other usually enters into it more or less.

CLAYS.

The clays are a dark red or blue, with some variations of yellowish and purple, and are calcareous and arenaceous. The blue clays are not very common, are nearly always highly arenaceous, and frequently contain vertebrate remains. The red clays are seen at nearly every outcrop, and are often more than a hundred feet thick, with probably a few thin layers of sandstone distributed through the strata.

THICKNESS AND UNCONFORMABILITY.

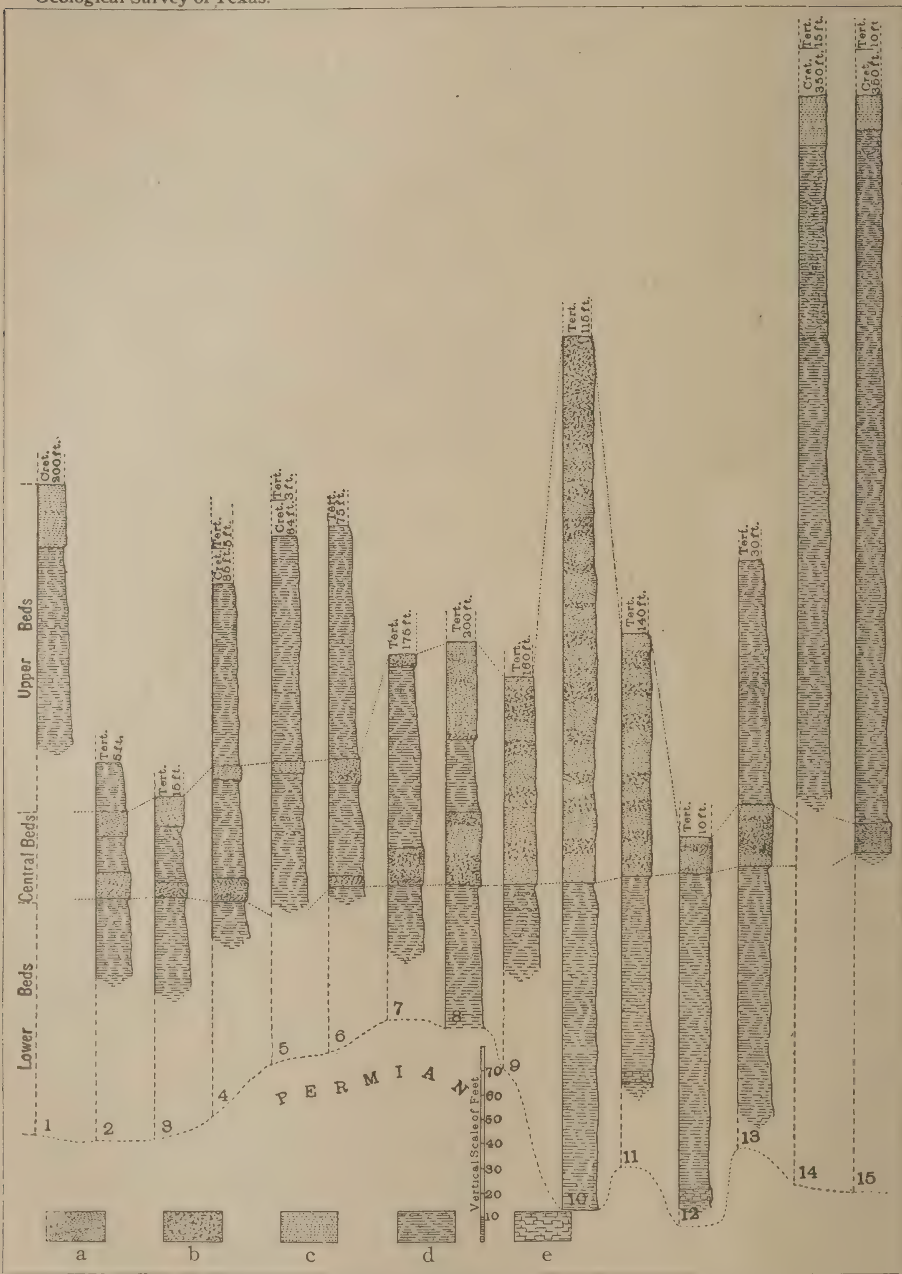
The slight difference in dip, and sudden change in lithological character of the Triassic beds from the Permian, point conclusively to a break in the sedimentation of the two formations. At some localities the Triassic beds are overlaid by Cretaceous, but generally by Tertiary material. The Cretaceous escarpment or buttes resting on the Triassic beds are often two hundred feet thick, and mostly limestone. The denuding forces that for an immense length of time were cutting these Cretaceons rocks back towards their present limits must have carried away a great deal of the Triassic before it was covered by Tertiary. The strata thus enclosed between two unconformable beds must of necessity vary in thickness, and so we find it varying from a few feet to nearly four hundred feet. Even in localities close together the beds vary considerably in thickness. The average, however, will probably reach two hundred feet.

STRATIGRAPHY.

The following classification or grouping of strata is not intended as a correlation with any other Triassic beds, but only to apply to the Dockum beds over the area examined. The Dockum may be divided into three beds, though some localities show more, that are more or less well-marked. The sections on Plate V show these beds as they occur at different places on the east and north side of the Plains from Signal Peak, Howard county, to Tucumcari Mount, New Mexico. These three main beds are as follows: A lower bed of sandy clay, which is from 0 to 150 feet thick; a central bed or beds of sandstone, conglom-

PLATE V.

Geological Survey of Texas.



SECTIONS SHOWING THE RELATION OF THE TRIASSIC BEDS OF THE STAKED PLAINS.

a. Cross-bedded sandstone. b. Conglomeritic false-bedded sandstone. c. Sandy clay. d. Clay. e. Calcareous sandstone.

erate, and some sandy clay, which is from 0 to 235 feet thick; an upper bed of sandy clay and some sandstone, which is from 0 to 300 feet thick. While these groups represent the different geological horizons over most of the Triassic area, there is nevertheless at some places a thinning out of one, and a thickening of another, which shows that at the same time the conditions of deposition were somewhat different at different localities. The same geological horizon is, therefore, more or less represented in other beds than that which generally represents it. Then, while these three beds do not absolutely represent geological horizons, they do so approximately, and are so well marked as to be of much stratigraphical value.

THE LOWER BED.

The lower bed of sandy clay occurs well marked lithologically at the base of all, or nearly all, of the Triassic area, and may usually be distinguished from the underlying Permian by being of a darker red color, more sandy, less stratified, and free from gypsum strata. At Iatan, Mitchell county, at least fifty feet of this lower or basal sandy clay may be seen in a section along the escarpment and adjacent ravines. Its thickness in Mitchell, Howard and Gordon counties must be something near one hundred feet, but becomes somewhat thinner in Garza, Crosby and Dickens counties, and in them will probably not average over fifty feet. In Dickens county it is quite frequently interstratified with a few thin layers of sandstone. Through Motley and Briscoe counties its thickness is considerably increased, and is somewhat more sandy and interstratified with thin layers of sandstone, especially toward the top. In Armstrong, Potter and Oldham counties the beds average in thickness over one hundred feet, with a slight increase toward the northwest. This increase most probably continues on to Liberty or Tucumcari mountains, New Mexico, though the base of the Triassic was not seen at these places. At most of the places where seen in the above named area this bed was less arenaceous than further southeast or southwest, and at some localities in Armstrong county it contains but little sand. Southward from Tucumcari it seems to become thinner, and may possibly not occur in the southeastern part of the Triassic area, though it most likely exists there. In the most western escarpment of the Staked Plains, in southeast New Mexico, east of Eddy and Lookout, there is forty to seventy-five feet or more of red sandy clay or clayey sand that most probably belongs to this lower bed. This outcrop extends southward, from about fifteen miles east of Eddy, to the east side of the Pecos river valley, five miles east of Lookout, but may not be continuous all the way. East of Eddy this stratum is about forty feet thick, and rests between the gypsum beds and the Tertiary strata. East of Lookout it is seventy-five

feet or more in thickness, and is overlaid by the Tertiary. The basal contact was not seen there.

East of Pecos City the strata lying between the Tertiary and the regular gypsum beds are red sandy clays and red sandstone of even grain and regular parallel bedding. The sandstone is tough and makes an excellent building stone, and is largely quarried. It is in two massive layers, three to four feet thick, with a great many thinner layers. The position of these beds places them with the Triassic, but their characteristics are so different from the Dockum beds material that I cannot say now just where they belong. If these are Triassic strata, as seems most probable, they undoubtedly belong to the lower bed, and have no outcrop in the eastern or northern border of the Dockum beds.

Going on south along the lower escarpment facing the east bank of the Pecos river, these red sandstones come down to the base of the escarpment and pass out of sight, and red sandy and black gypsiferous clays come in under the overlying Tertiary and continue in an outcrop of eight or ten feet down to a point northwest of Castle mountain, where the escarpment is lost in rolling lands that are often covered with sand beds. These sandy clays, or clayey sands, are probably a part of the lower beds of the Triassic.

THE CENTRAL BEDS.

The Central beds of sandstone, conglomerate, and sandy clay are represented in the southeastern part of the Triassic area by sandstone and conglomerate strata interstratified with sandy clay.

There are, however, but two very well marked sandstone and conglomerate horizons, as may be seen by referring to the comparative sections, Plate V. The strata of each vary in thickness from three or four feet to twenty-five or thirty feet, and it may be that they are not altogether continuous. The variations in thickness are more or less conspicuous throughout the entire extent of the two horizons, and there is nearly always a marked distinction between them in the northern part of Garza county, all the way across Crosby and Dickens counties, and in the northern part of Motley. In these localities the lower horizon is more especially characterized by the siliceous pebbles, and is usually thicker than the upper. Towards the northern part of Motley county the two beds increase in thickness, come together, and continue as one distinct bed to Liberty, New Mexico. From the point where the two unite and form one bed it increases in thickness toward the north and northwest, and gradually loses its siliceous pebbles, until in Armstrong county it is almost entirely destitute of them, and is two hundred and twenty-five feet thick. From Armstrong county north and northwest it thins out quite rapidly, and is but about twenty-five feet thick at Tucumcari mountain, New Mexico.

North and south of Fort Sumner, New Mexico, the Central bed increases considerably, but contains some sandy clays or clayey sand strata.

At the salt lake, about twenty-five miles east of Eddy, New Mexico, this bed is shown in alternating sandstone, sandy clay and conglomeritic calcareous sandstone strata. See section, plate V.*

In wells at and near the Cowan ranch, about thirty-five miles east of Lookout, New Mexico, this sandstone and conglomerate horizon is reached under a few feet of Tertiary strata. At Castle mountain red sandstone, sandy clays and conglomeritic sandstone underlie the Cretaceous strata, and very probably belong to this Central bed.

UPPER BEDS.

The upper beds, of sandy clay and some sandstone, is thickest where overlaid by the Cretaceous formation, and rapidly thins and disappears away from the Cretaceous border. The denudation of post-Cretaceous times carried away the most of these beds where there was no overlying Cretaceous stratum to protect them. So we have left only remnants of the upper beds under and around the Cretaceous in the southeastern part of the Triassic field, at Tucumcari mountains and vicinity, New Mexico, and possibly under the Cretaceous at Castle mountains, Crane county.

In Howard county these upper sandy clay beds under the Cretaceous formation are about one hundred feet thick, and at Signal Peak and vicinity have some false-bedded sandstone at the top.

In Borden county they are eighty or ninety feet thick, and extend quite a distance into Garza county.

From northern Garza county around to Oldham county these upper beds are wanting, but in southwestern Oldham they occur and increase in thickness toward the west and the Cretaceous, until at Tucumcari mountains they reach a thickness of three hundred feet. South of the Cretaceous area near Tucumcari mountains they soon disappear, and likely do not occur anywhere down the west part of the Dockum beds unless at the Castle mountains.

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* The sections on this plate show the relations of the Triassic to the overlying and underlying beds at the following localities:

1. Signal Mount, Howard county. 2. Four miles southwest of Iatan. 3. Half mile south of Iatan, Mitchell county. 4. Muchakooyo Peak, Borden county. 5. Three miles south of Double Mountain Fork of Brazos river, Borden county. 6. Two miles north of Double Mountain Fork of Brazos river, Garza county. 7. Four miles northeast of Dockum, on Duck creek. 8. Devil's creek, Dickens county. 9. Head of Jones creek. 10. Southwest corner Armstrong county, in Palo Duro canyon. 11. Three miles northwest of Amarillo. 12. Thirty miles south, 60 degrees east, from Big Tucumcari Mount. 13. Head of East Fossil creek. 14. Big Tucumcari Mount. 15. Fifteen miles southwest of Big Tucumcari Mount.

DIP OF THE FORMATION.

The approximate average dip of the Triassic beds is to the southeast, and about eight feet per mile. In some localities there is almost no dip, and some places show a dip to the northwest or north, but this is rare. The greatest dip is in the northern and northwestern part, and in Potter and Oldham counties it increases to fifteen or eighteen feet per mile, in some places even more. The western part also seems to have a greater dip in places, and a little more toward the south.

SPRINGS.

There are comparatively few springs on the north and west sides of the Triassic escarpment at the base of the Staked Plains, while on the east side they are abundant. Most of them come from the north and west sides of the ravines and canyons which extend back into or through the Triassic strata. These facts are explained by the dip and character of the Dockum beds and the character of the overlying and underlying beds. The Permian and lower beds of the Triassic are mostly impervious clays, so that the waters from rains and snows percolate down through the porous overlying Tertiary to the Triassic sandstones and conglomerate, through which the water runs down to an opening on the lower side.

That springs are not abundant in the southeastern part of the Triassic beds is doubtless due to the sandstone and conglomerate being thinner and probably not continuous, and to the more horizontal position of the beds. From Crosby county to the center of the eastern part of Armstrong county springs are very abundant. This belt embraces the outcropping Triassic area which contains the thickest beds of sandstone and conglomerate, and over this area there is no doubt as to the continuity of these strata.

DEPOSITION.

The fossils and characteristic material of these beds show that they were deposited in an inland fresh water basin. The vertebrate fossils, as determined by Professor E. D. Cope, were shallow water animals. The *Unios* found were also shallow fresh-water species. The drift material of the conglomerates, the alternating and changeable layers of sandstone, grit, and clayey sand all show a record of shore or near shore deposits. The dip of the layers of the false-bedding of the sandstones and conglomerates is generally towards the northwest, but often towards the north or west, which indicates that the shore-line of these deposits was to the south and east with the center of the inland basin to the northwest. The thickening of the formation toward the northwest also points to such a conclusion. The indications are, however, that the beginning and close of the Dockum beds period, when the finer and more uniform sediment of sandy clays, or clayey sands, was deposited, was an era of somewhat deeper and less turbulent waters.

LOCAL DEVELOPMENT.

The first of the Dockum beds studied in the past season were at and in the vicinity of Iatan, Mitchell county, and the adjoining eastern part of Howard county, along the breaks of Giraud, Wild Horse and Morgan creeks. The upper parts of the beds, with a cap of Tertiary strata, form an escarpment about one hundred feet high to the southwest and northwest of Iatan, extending to within half a mile of Iatan to the south, and receding toward the northwest.

Just south of Iatan the escarpment shows the following section, No. 3, Plate V.

1.	Tertiary deposits of sand, siliceous pebbles, and calcareous hardened clay	15 feet.
2.	Crossbedded micaceous grit	12 to 14 feet.
3.	Dark red arenaceous clay	25 feet.
4.	Shaly micaceous sandstone and grit	6 feet.
5.	Chocolate colored clay, slightly arenaceous	40 feet.

The clays of the Triassic beds, wherever seen near Iatan, have the same general characteristics, such as chocolate color; scattering small scales of white mica, slightly to highly arenaceous; and scattering small spots of bluish sandy clay, which sometimes form thin layers and contains pieces of shaly sandstone. The sandstones vary somewhat at different places comparatively near each other. In the above section, No. 4 is false-bedded, and is so full of mica that the rock is very fissile. Following this stratum along the outcrop westward, it is found to lose this character to a large extent, and becomes a somewhat shaly sandstone with only a small quantity of mica. Near Iatan the upper part of this stratum is composed of coarse sand and scattering small sandstone pebbles, and bluish argillaceous spots and specks are quite common through the rock. The mica in the sandstones and clays varies in size from mere specks to flakes one-eighth of an inch in diameter, and is nearly all white, only a few scattering black pieces occurring. No. 2 of the above section, or the upper sandstone and grit stratum, also changes considerably, as is shown along its outcrops towards the northwest and southwest. At Iatan this stratum is a massive, highly micaceous, friable grit, showing here and there many wavy lines of false-bedding, and contains some nodules of ferruginous sand one or two inches in diameter. Following the outcrop of this stratum one and a half miles along the escarpment to the northwest, it disappears, and the Tertiary formation rests on the lower strata of the Dockum beds, but going a short distance along the escarpment, the stratum appears again, and is a more even, fine grained rock, and reaching almost twice the thickness it has at Iatan. Some of the smooth, evenly textured, white sandstone layers are seven or eight feet thick, but are friable, there being but few layers which could be used for building purposes.

In the breaks of Giraud creek, three or four miles southwest of

Iatan, the Triassic rocks are well exposed and vary but little from the section at Iatan, except that the lower sandstone stratum contains very little mica and is more uniformly white and massive; still it is somewhat shaly at places and always false-bedded. At this place about twenty feet of the red clay belonging to the Dockum beds rest on the upper sandstone stratum. Near the top of this red clay there are a few thin layers of bluish clay and sand. At this locality, which is at and southeast of the water tank of the Texas and Pacific Railway, the beds show a well-marked dip to the northwest for more than a mile, and the red clays, with a few interstratified sandstone layers, seem to thicken slightly to the west or southwest where the Tertiary strata overlays them. There is here an area of one and one-half or two miles square from which erosion has removed the Tertiary strata, and also the Dockum beds, down to the sandstone stratum. At Signal Peak, which is about fourteen miles southwest of Iatan, or fifteen miles southeast of Big Springs, Howard county, the Dockum beds are covered with nearly two hundred feet of Cretaceous strata, and consequently show a higher horizon of the Triassic beds. The lowest Triassic strata seen there consist of more than eighty feet of dark red arenaceous clays, which contain some shaly sandstone near the top. Bluish spots and specks occur throughout this stratum. Above this clay, and at the top of the Triassic, there is twenty-five feet of sandstones varying from massive to false-bedded and shaly, and from a friable white rock to a moderately hard red or nearly white stone. Small flakes and specks of mica are scattered through all the strata. These sandy clays and some sandstones occur along the entire base of the Cretaceous escarpment to Big Springs, Howard county, and some outcrops occur west of Big Springs. Southeast of Signal Peak, on either side of Giraud creek, the Triassic beds occur in the valley, and small outcrops along the breaks of the creek. About two miles east of Marienfeld is an escarpment about fifty feet high, which for several miles runs approximately north and south. The north part becomes lower and lower till it is lost in the plains, and the south part bends eastward to meet the Cretaceous escarpment which extends westward from Big Springs. The top part of this escarpment is Tertiary, and rests on about ten feet of Triassic sandstone, which contains siliceous pebbles in such numbers as to make the rock a conglomerate in places. The mass of this rock is made up of white sand with an occasional red grain, all of which are rather coarse and almost make the rock a grit. The stratum is friable, and in places is slightly false-bedded, but has regular layers and is not a uniform mass of compact sand. Below this stratum is twenty-five or thirty feet of red sandy clay interstratified with some red shaly sandstone. These rocks have a considerable outcrop toward the southeast, but soon dis-

appear toward the north as the escarpment becomes lower and less abrupt.

Strata belonging to the Dockum beds occur along the escarpment of the Staked Plains northward from Iatan, but the escarpment along Wild Horse and Morgan creeks consists principally of the Tertiary strata. The Dockum beds are better exposed in the rolling country just east of the escarpment. About four miles north of the head of Morgan creek, the escarpment, or sharply rolling land, extends westward up the south side of the Colorado river valley, and consists of the red arenaceous clay and red micaceous sandstone of the Triassic. Further to the west, or just west of the Big Springs and Gail road, Tertiary strata again overlie the Dockum beds. Three-fourths of a mile north of the Colorado river, and about that distance east of the Big Springs and Gail road, the following section was made, beginning at the top:

1.	Sandstone, mostly white, varying from massive to shaly, friable and slightly micaceous, the upper part graduating to a grit	3½ feet.
2.	Compact white sand	2 feet.
3.	White argillaceous slightly selenitic sand, which rapidly graduates into the red arenaceous clay below	

The rolling country, for several miles west, north and northeast, often shows freshly eroded Dockum beds sandstone and red sandy clays. At Muchakooyo Peak, about four miles southeast of Gail, Borden county, and in the escarpment southwest and west, and northwest of Gail, the Dockum beds are overlaid by nearly one hundred feet of Cretaceous strata. The Muchakooyo Peak section, No. 4 of cut on Plate V, beginning at the top, is as follows:

1.	Tertiary beds (mottled limestone)	5 feet.
2.	Cretaceous limestone	65 feet.
3.	Trinity sands	20 feet.
4.	Dark red clay (top of the Dockum beds)	40 feet.
5.	Massive to shaly, friable white to reddish sandstone	5 to 6 feet.
6.	Red sandy clay	45 feet.
7.	Blue sandy clay	4 feet.
8.	Sandstone, varying from white to gray. In some places the rock is a conglomerate of siliceous pebbles and coarse sand, and in places it contains small pieces of indurated argillaceous blue clayey sand	5 feet.
9.	White compact sand, containing clay, mica and siliceous pebbles	5 feet.
10.	Red clay, with bands and streaks of blue clay	. . . .

The base of the buttes and escarpments near Gail show the same character of strata as the above section, with a slight variation in the Dockum beds sandstone, which are there somewhat more shaly and not so coarse grained, and have a more reddish color. Most of the Dockum beds that can be seen, however, is the red sandy clay.

Twelve or thirteen miles about north-northwest from Gail the Cretaceous strata in the escarpment end, and the Tertiary strata rest on the Dockum beds.

In the northeast corner of Borden county and parts of the adjoining counties, there is a mesa which is principally composed of Cretaceous rocks.

About three miles south of the Double Mountain Fork of the Brazos river the following section was made of the northwest side of the above mesa. Section No. 5 of Plate V:

1. Mottled limestone (Tertiary) . . . . 3 feet.
2. Cretaceous strata . . . . 60 feet.
3. Red sandy clay, interstratified with a great many thin shaly layers of red or blue sandstone and a few thin layers of blue sandy clay . . 90 feet.
4. Sandstone, white, varying from massive to shaly, and from a coarse grained to a grit and even a conglomerate. Small pieces of bluish clay and pieces of indurated white clayey sandstone are scattered through this stratum . . . . 5 feet
5. Dark red sandy clay, containing a very few thin short veins of selenite and thin layers of shaly sandstone . . . . 60 feet.

Small pieces of mica occur all through the Dockum beds of this section. For three or four miles west of this section erosion has laid bare a great deal of the red sandy clay and shaly sandstones of the Dockum beds, and possibly has extended down into the Permian strata, as some of the lower rocks exposed contain salt. Just north of the river, opposite the above section, the escarpment and buttes are capped with Tertiary strata, and a lower horizon of the Dockum beds is shown. Probably half of the following strata of Dockum beds are of a lower horizon than the above section. See No. 6 of Plate V.

1. Tertiary beds . . . . 75 feet.
2. Blue clay, containing a three inch layer of ferruginous conglomerate . . . . 3 feet.
3. Red sandy micaceous clay, with an occasional thin short seam or vein of selenite; also a little red shaly sandstone . . . . 170 feet.
4. Massive false-bedded conglomeritic sandstone, varying in color from white or gray to red . . . . 10 feet.
5. Red sandy clay, with a little blue gypseous sandy clay at the top . . 40 feet.
6. False-bedded conglomeritic sandstone and argillaceous sandstone, containing many *Unio* fossils . . . . 4 feet.
7. Red sandy clay . . . .

No. 4 of the above section contains a few siliceous pebbles, but yellowish brown and greenish sandstone pebbles make most of the conglomeritic nature of the rock. Small pieces of indurated sandy clay are also found in it. The mass of this bed is rather coarse white sand, and sometimes is free from pebbles. The country lying just east of this section or escarpment is exceedingly broken. Deep gulches wind their way toward the river through these sandstones and sandy clays, leaving

the sandstones projecting as benches and the sandy clays carved into steep banks or rolling surfaces.

The white friable sandstones are quite characteristic in the Dockum beds through Garza county. Most of these are represented by No. 4 of the above section. This stratum is also quite uniform and persistent in its characteristics, and for fifteen or twenty miles northward from the Double Mountain Fork of the Brazos river it forms a marked topographical feature. Along its outcrops and escarpments, near Yellow House Canyon creek, masses of ferruginous sandstone concretions eight to ten inches in diameter occur scattered through it.

Near the north side of Garza county the siliceous conglomerate becomes more characteristic of the Dockum beds, and along the banks of the Salt Fork of the Brazos, south and southwest of Dockum, this siliceous conglomerate appears in beds twenty to thirty feet thick. Often the larger part of the rock mass is composed of siliceous pebbles, and part of the rock is almost a solid mass of them.

From just north of the northeast corner of Borden county the Tertiary escarpment recedes westward and northwest until it passes Yellow House canyon and the Salt Fork of the Brazos, then comes back northeasterly to the southeast part of Crosby county. Within this area, and to the east of it, the Dockum beds spread out to a considerable extent, but they are much covered and hidden by sand beds from the denuded Tertiary deposits above. The following section was made on MacDonald's creek, about one and one-half miles below the most eastern escarpment of the Plains:

1. Massive cross-bedded coarse grained sandstone, the lower part containing many siliceous pebbles . . . . 20 feet.
2. Covered with detritus from No. 1 . . . . 10 feet.
3. Conglomerate of siliceous pebbles and brownish sandstone pebbles. *Unio* fossils are common in this layer . . . . 1 foot.
4. Red argillaceous sand . . . . 10 feet.
5. White false bedded sandstone, with conglomerate and *Unio* fossils at the base . . . . 5 feet.
6. Red sandy clay . . . . 5 feet.

The Dockum beds, wherever seen in eastern Crosby county or western Dickens county, always showed false-bedded micaceous sandstones, siliceous conglomerates, red sandy clays and bluish sandy clay. The siliceous conglomerates are well exposed in White river at and below the falls, near the windmill north of Dockum, and at Duck creek west of Espuela, and are false-bedded, the layers dipping to the southwest and west. The amount of sand or grit in the conglomerate varies, but the siliceous pebbles are the most prominent feature of the mass, and often compose most of the bed, and it is overlaid by about twenty-five to seventy-five feet of red sandy clay, sometimes containing vertebrate and *Unio* fossils. Bluish clay also occurs at many places in this stra-

tum, sometimes also containing vertebrate fossils. This twenty-five to seventy-five feet of clay is in turn overlaid by from five to forty feet of white sandstone, false-bedded in places, and conglomeritic in places, although this latter feature is rather uncommon. Some of the bed is a grit, and small pieces of bluish and yellowish brown indurated arenaceous clay are often scattered through it. Small flakes of mica also occur in it very abundantly at places, and the *Unio* fossils are found near the base. These *Unios* are very abundant at this horizon at the head of Duck creek. Pieces of lignite and pieces of silicified* wood are frequently imbedded in the sandstones or conglomerates. Fifty or sixty feet of sandy clay, often interstratified with thin layers of sandstone, lie under the lower conglomerate mentioned above. About a mile southeast of the Espuela Headquarters ranch the most of this basal Dockum beds horizon occurs.

The characteristics of the Dockum beds in Dickens county continue, with minor variations, into the southwest part of Motley county. In the latter county, along the headwaters of the Wichita and Pease rivers, the lowest siliceous conglomerate is underlaid by a red compact and often quite firm sand, containing a very small amount of clay. At the above localities a massive Quaternary conglomerate often overlays the Dockum beds. This conglomerate may be distinguished from the Triassic by its containing Cretaceous fossils, coarser pebbles, and some different kinds of pebbles, and by being less compact. The matrix of the Triassic conglomerate is usually slightly calcareous. The sandstones and conglomerates thicken quite rapidly toward the northern part of Motley county, where they reach about one hundred feet in thickness. On Jones creek this bed and part of the lower beds are beautifully exposed. The Central beds are there a white micaceous conglomeritic sandstone, the larger part of which is false-bedded, the layers dipping westward and northwest, and sometimes north. Nearly all of this bed contains some siliceous pebbles, which are small and well rounded, and about one-half of the bed contains a great many of them. Little rounded pieces of hard brownish or dove colored sandy clay stone are also quite common. This rock is generally too soft for building purposes, yet occasional layers may be found firm enough to be of value as a building stone. The lower beds of the Dockum beds here are a dark red sandy clay containing at the top several alternating layers, one to two inches thick, of red friable sandstone. Layers of false-bedded reddish sandstone, two to three feet thick, occur every eight or ten feet from the top of this bed down thirty or forty feet, where the bed becomes more argillaceous and has fewer sandstone layers. The false-bedding layers dip to the northwest.

There is very little change in the Dockum beds northwards to the

* For the occurrence of silicified wood in the Dockum beds in Dickens county, see Second Annual Report, page 427.

southeast corner of Briscoe county, except a slight increase in thickness of the sandstones and conglomerates, and a decrease of the number of the siliceous pebbles in the conglomerates. At Holmes creek, in the southeast corner of Briscoe county, the sandstone and conglomerate bed is over a hundred feet thick, and is mostly a massive even-textured white sandstone. Very few siliceous pebbles are in the conglomeritic rocks. The lower beds of the Dockum beds here are a dark and red argillaceous sand with some layers of red sandstone, with a little bright yellow clay containing nodules of crystalline calcite near the top.

The numerous branches of Prairie Dog Town Fork of Red River in Briscoe county have worn the eastern limit of the Tertiary and Dockum beds westward, so that in our line of work northward we did not reach these beds again till we got to Goodnight, Armstrong county. Near the mouth of Mulberry canyon, three or four miles southwest of Goodnight, all of the Dockum beds are worn away except about forty feet of the lower beds of sandy clay, or at this place clayey sands. The increasing thickness toward the north and northwest of the sandstones and conglomerates, as indicated in Motley county and southeastern Briscoe county, continues on to Palo Duro canyon, Armstrong county, where it reaches a thickness of two hundred and twenty-five feet. From the falls in Palo Duro canyon, south of Amarillo, to the mouth of the canyon, there are but two principal beds of the Dockum beds, although local variations of alternating sandstones, conglomerates and sandy clays, occur at different places. Usually over two hundred feet of the upper part of the Triassic is sandstone and conglomerate, while over a hundred feet at the base of the formation is clay slightly arenaceous.

The contact between the Dockum beds and the underlying Permian is clearly marked. Both the color and lithological characteristics of the two formations bear a striking contrast. The Permian is a bright red argillaceous sand, slightly shaly, though sometimes massive, is characteristic for stratification planes, and below the top forty feet is interstratified with massive and fibrous gypsum, the gypsum becoming more abundant toward the base of the section exposed. The Dockum beds, arenaceous clays, in contact are a yellowish purple or a yellowish red, sometimes decidedly yellowish. The bedding is usually uniform and lacks the stratification planes so characteristic of the Permian. The contrast between the formations along their contact is so great that the contact may be located as far as the eye can see stratification planes in the freshly eroded outcropping bed, or as far as it can distinguish sharply contrasting colors.

The top part of the Dockum beds down the canyon is white sandstone, generally cross-bedded and conglomeritic. It is occasionally interstratified with thin layers of bluish clay, or more rarely with a

thicker layer of red sandy clay, such as is at the base of the bed, except that it is more sandy. The sandstones and conglomerate contain small flakes of mica. Fossil reptilian teeth, bones, and coprolites frequently occur in the conglomerate, but siliceous pebbles are extremely rare. The conglomerates are made of a matrix of sand with varying proportions of crystaline calcite and pebbles of sandstone, or clayey sandstone, varying in color from white or gray to dark shades of brown. Small pieces of reddish sandstone also occur in them. The cross-bedding layers dip to the west or northwest. Some of the conglomerate is firm enough for building purposes, especially where it contains considerable lime. The massive sandstones are, however, too soft to stand much pressure or resistance to weathering. Pieces of lignite and fossil wood occasionally occur in the sandstone and conglomerate.

The relative amount of sandstone, conglomerate and clay varies at different localities down the canyon. The conglomerate predominates on Rush creek, clay on Happy creek, and even-grained sandstone on Pleasant creek. On Home creek and Pleasant creek the thickness of the sandstone and conglomerate stratum is about two hundred feet, on Happy creek and Rush creek it is about two hundred and twenty-five feet, but the total thickness of the Dockum beds at all these places is approximately the same. The sandstone and conglomerate beds in Randall county, just below the falls in Palo Duro canyon, are about one hundred feet thick. Some of the top layers of these beds form the falls. At this locality the sandstones and conglomerate are about equally divided in amount and bear the same characteristics as the same bed down the canyon in Armstrong county. About three miles down the canyon from the falls the following section is made. See section No. 11 of Plate V:

1.	Tertiary strata	75 feet.
2.	Conglomerate and friable evenly textured sandstone	100 feet.
3.	Sandy clay, red, purple, yellowish, sometimes blue	80 feet.
4.	Yellow clay and calcite nodules	5 feet.
5.	Red sandy clay	

No. 4 of the above section is a mass of crystaline calcite and bright yellow clay, the clay usually being greater in amount. Thin seams of crystaline calcite intersect this stratum in every direction, and calcareous nodules with centers of crystaline calcite are quite common scattered throughout the stratum. The stratum of yellow clay and crystalline calcite nodules in southeastern Briscoe county, on Holmes creek, is probably the same horizon as stratum No. 4 of the above section. As will be seen further along this stratum occurs north and northwest of Amarillo.

The sandstone and conglomerate bed so finely developed in Palo Duro

canyon was almost worn away eighteen or twenty miles to the north, before being covered up by the Tertiary beds.

The northern escarpment of the Staked Plains extends westward through Potter county, passing about three miles north of Amarillo, where eight or ten feet of the Tertiary strata overlays the Dockum beds, and the central beds of the sandstone and conglomerate is only about fifteen feet thick. This conglomeritic sandstone contains considerable lime and makes an excellent building stone. It is firm and tough, has a uniform composition, and dresses well. It is largely quarried and used for building purposes in and near Amarillo. In the bed of West Amarillo creek, about four miles northwest of Amarillo, the same stratum of bright yellow clay and crystaline calcite nodules occurs as seen in Palo Duro canyon three miles below the falls.

On West Amarillo creek there is about one hundred and thirty feet of red sandy clay between the Palo Duro of the central beds and the yellow clayey stratum. The central beds increase in thickness westwards from West Amarillo creek, but the sandstones and conglomerates are interstratified with red and purple clay.

In the eastern part of Oldham county the yellowish clay and calcite stratum is still a conspicuous horizon, and has about the same thickness as in Palo Duro canyon. The central beds are there twenty-five or thirty feet thick, and are mostly white massive sandstone. Red clay interstratified with a little shaly sandstone occurs at the top of the Dockum beds, and is probably the lower part of the upper bed as seen further west.

In the central part of Oldham county a branch has cut its way back several miles into the Tertiary, and worn down through the upper horizon of the Triassic false-bedded sandstone and conglomerate, and part of the lower red sandy clay. The false-bedding, the small mica flakes, and all the characteristic features of the Dockum beds, except the siliceous conglomerate, are there represented.

The next place we saw the Dockum beds was where the old government or Santa Fe trail goes down off the Plains at the head of Rocky Dell creek, in the southwestern part of Oldham county. The red arenaceous clay predominates there, but the central beds are represented by at least twenty-five feet of false-bedded micaceous white sandstone, some of the massive sandstone layers of which are five or six feet thick. This bed has also red calcareous false-bedded conglomeritic sandstone. Layers of the false-bedding dip to the west or a little south of west. The bedding contacts between the sandstones and conglomeritic layers often present very wavy planes. About one hundred feet of red sandy clay lies between the above bed and the overlying Tertiary strata, and more than one hundred feet of red sandy clay lies below the sandstone bed. The exact line of contact between the Dockum beds and the Permian is not clearly marked in Rocky Dell creek.

The principal change to the westward in the rocks of the Dockum beds, as seen along the foot of the Staked Plains for twenty-five or thirty miles into New Mexico, is that the clays become more sandy and the white sandstone and conglomerate gets a little thinner, but retains the same characteristics. Pieces of lignite, silicified wood, and reptilian bones are still sparsely scattered through the conglomerates and sandstone.

About thirty miles south 75 degrees east from Big Tucumcari mountain the Dockum beds are overlaid by Cretaceous strata, and the upper beds are much thicker than further east, and show some change in that they are interstratified with thin layers of red and white sandstone, the layers of sandstone becoming somewhat thicker lower in the formation. The clays are often highly arenaceous, dark red, bluish white, and in some places a light red. At the foot of the Plains, about twenty miles southeast of Big Tucumcari mountain, or at the head of East Fossil creek, there is over one hundred feet of the upper bed shown in the base of the escarpment. This is red clay, slightly shaly in places, and more or less sandy throughout, interspersed with thin layers of blue and purple clay. Layers of sandstone, from one inch to three feet in thickness, are also sparsely distributed through the section. The sandstone is generally white or bluish, but some of the thin layers are red, or red with blue spots.

Down East Fossil creek, about two miles from the escarpment, and over two hundred feet below the top of the Dockum beds, the white sandstone and false-bedded conglomeritic beds are worn through by the creek. These beds are about twenty-five feet thick and rest on red sandy clay as usual.

At Big Tucumcari mountain only the upper beds can be seen, and the lower forty or fifty feet of them is hidden in the rolling country around the mountain. But the part visible in section is beautifully shown to the base of the mountain, especially on the north side of it. These upper beds contain three different beds. The top one, overlaid by Cretaceous sandstone, is the chocolate colored sandstone, about twenty feet thick. It is rather hard and brittle, and breaks and weathers with a conchoidal fracture. The layers composing this bed vary in thickness from massive layers of five feet to layers of three inches. Thin layers of sandy clay are interstratified through the center of this bed, and five or six feet from the base there are two six-inch layers of conglomerate, with white and colored, small, well rounded siliceous pebbles in a matrix of sand. The next bed below is eighty feet of highly arenaceous clay, its color varying from chocolate to purple, with streaks and spots of bluish and greenish white scattered through the base, and forming almost regular bands or layers near and at the top, but the structure throughout is massive and uniform. The third bed below consists of about two hundred feet of chocolate colored clay,

only slightly arenaceous, uniform in structure, and without planes of stratification.

All three of these beds graduate into each other, and the exact line of division given is merely arbitrary. These upper beds may be seen well exposed in the bases of the peaks, buttes, and escarpments for miles around Tucumcari mountains.

The escarpment of the north side of Pijarro creek northwest of Big Tucumcari mountain does not show so much of these beds as the escarpment in other directions from the mountains.

About fifteen miles south 30 degrees west from Big Tucumcari mountain the base of a butte shows about two hundred and eighty feet of the upper beds. (Section No. 15, Plate V.) This section has the same beds as the Tucumcari section, but the upper two are much less marked, and together are only about forty feet thick. All of the section, however, has more sand than it has at Tucumcari mountain, and even the basal part has thin layers of shaly sandstone. About two miles south of this butte, and forty or fifty feet below the above section, in the banks of a branch of Fossil creek, is exposed ten or twelve feet of the white micaceous sandstone of the central beds. This sandstone is shown all along Fossil creek and its branches southeast of Big Tucumcari mountain, and in a number of places in the creek banks between the main Fossil creek and East Fossil creek.

The escarpment of the Staked Plains just south of the Tucumcari mountains has no Cretaceous strata, and the Tertiary beds again overlie the Dockum beds, and the upper beds again show the effects of greater erosion by the thinness of the part remaining.

About thirty-five miles southwest of Tucumcari mountains, at the western escarpment of the Staked Plains, the central and the lower beds are spread out over a considerable area, but only the central beds are well shown in the face of the escarpment and the eroded banks of the adjacent ravines. Alternating layers of red sandy clays are associated with the sandstones and conglomerates. The sandstone layers are the white friable micaceous rocks so characteristic of these beds. The conglomerates have no siliceous pebbles, and the sandstone pebbles are small sub-angular fragments as usual. The rolling country from the above escarpment to the Pecos river is gentle, with but few places of exposed strata, and the exact line of contact between the Dockum beds and the Permian cannot now be given. The formation along the Pecos river about Fort Sumner is shown to be the Permian from the gypseous character of the strata; but this Permian belt, worn into by the river, is but a few miles wide, and the Dockum beds strata extend down the river on either side. Going south from Fort Sumner, soon after crossing the river to the west side, a slightly higher elevation is reached, which continues southward in an almost level plain for sixteen or eighteen miles, and there is no good exposure of the strata till Coyote

creek is reached, which is twelve miles south of Fort Sumner. Strata of the central beds are beautifully exposed along the banks of this creek, and have about the same relative proportions of sandstone, conglomerate and clays as along the western escarpment of the Staked Plains north of Fort Sumner, but there is probably a little more conglomerate in the section. A Quaternary conglomerate lies on the top of the Dockum beds along Coyote creek.

After going four or five miles further south we pass down off the Dockum beds on to the Permian, and on our line of travel southward we saw no more of the Dockum beds west of the Pecos river. We next crossed to the east side of the river and examined the western escarpment of the Plains, opposite Eddy, New Mexico.

East of Eddy there are two escarpments of the Plains. The western one was examined about fifteen miles northeast of Eddy, near the Clayton wells. At that point forty or fifty feet of argillaceous red sand lies between the gypsum and Tertiary beds, as is shown in the section from Eddy east to the top of the Plains. Ripple marked flakes of sandstone and bluish specks and spots are scattered throughout this strata. From its position and general characteristic there can be but little doubt that it is the base of the Dockum beds.

Twelve or fifteen miles further east, at a higher elevation, between the two escarpments, a salt lake basin extends down through the Tertiary into the central beds of the Triassic. The strata in the west bank and bottom of the lake were red sandy clay, bluish sandstone, red shaly sandstone, and a false-bedded calcareous sandstone slightly conglomeritic. The false-bedding dips to the north, and the conglomeritic nature of the rocks is due to small pieces of yellowish and brownish indurated clayey sandstone.

The above strata extends about twenty feet above the bottom of the ake, at the west end, but are not to be seen on the northeast side. The conglomeritic false-bedded horizon forms the bottom of the lake on the west side, but its thickness could not be determined. The mica flakes are not very abundant, and are usually very small, but all the strata contains some of them. The continuation of the escarpment from Clayton wells extends down near the river east and southeast of Lookout, New Mexico. This escarpment, east of the mouth Black river, has forty or fifty feet of red sandy clay with variations of yellowish and bluish clay. Five or six miles further south, this escarpment shows over fifty feet of this material and the entire thickness is probably over seventy-five feet.

About thirty miles east of the mouth of Black river, near the Nash ranch, and at the Cowan ranch, the wells are in the Triassic most of their depth. About five miles east of the Cowan ranch a well was sunk one hundred and forty feet and afforded very little water. After passing through a few feet of Tertiary strata on top, bluish sandstone,

clay and conglomeritic sandstone were passed through. The sandstones were the white, even-textured, friable and slightly micaceous sandstones so common in the Triassic.

The wells at the Cowan ranch are in a basin where the Tertiary beds are gone. These wells are about forty feet deep and afford plenty of water. The rock passed through in digging them is a conglomerate of clayey sandstone fragments in a matrix of clayey sand and crystaline gypsum. The gypsum is regularly distributed through the conglomerate, and varies somewhat in amount in the different strata passed through. The rocks have a bluish color when freshly exposed. Small flakes of mica are quite common in the sandstones at these wells.

Our work from Black river south, being on the west side of the river down to Pecos City, we saw no more of the western escarpment of the Plains till we reached the east side of the river opposite Pecos. The escarpment or sharply rolling land of the western limit of the Plains extends down by Quito on the Texas and Pacific Railway, and gradually gets nearer the river southward till only a narrow belt of level land is between it and the river.

Usually but eight or ten feet of Tertiary strata caps this escarpment, and about the same amount of red sandy and slightly gypsiferous clay forms the base. At Quito the basal part is composed of two massive red sandstone layers, each three or four feet thick, with some thinner layers of sandstone and sandy clay between and below them. These sandstone strata extend about sixteen miles southward, gradually getting lower till they pass under the base of the escarpment. They are quarried to a considerable extent near Quito, and shipped to distant points over the State for building purposes.

The probability of these being Triassic strata and their position in that formation has already been given.

At Castle mountain the Cretaceous is underlaid by red sandstone, conglomeritic sandstone and red clays of the Dockum beds. There is about thirty feet of this material exposed, and most of this is a red conglomeritic sandstone containing small pieces of calcareous clay, and sandstone of yellowish and brown colors; also pieces of reddish brown sandstone and calcite crystals. At the center of this thirty feet is red shaly sandstone and red marly clay. The shaly rock contains mica flakes. The outcrop of these beds is on the west side of the mountain and escarpment. The Cretaceous detritus hides them from view to the southward, leaving only a small area on the northwest side of the mountain where Triassic strata can be seen.

REPORT

ON

PALEONTOLOGY OF THE VERTEBRATA.

BY

E. D. COPE.

REPORT

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I. FAYETTE FORMATION.

In the First Annual Report of the Geological Survey of Texas (p. 47), Mr. R. A. F. Penrose, Jr., describes this formation as it occurs in south and east Texas. He places it at the summit of the Tertiary series and below the "Post-tertiary;" that is, at the summit of the Neocene, just prior to the advent of the Pleistocene. This location is justified by the only vertebrate fossils definitely traceable to these beds, which have been sent me for identification by Mr. E. T. Dumble, State Geologist of Texas. One of these consists of a well-preserved left ramus with symphysis and nearly complete dentition of the mandible of the large lama, *Holomensicus hesternus* Leidy. This species is characteristic of the Equus beds of Oregon, California and Mexico, and indicates satisfactorily the age of the formation in which it occurs. It confirms fully the position assigned to the Fayette beds by Mr. Penrose and by President Chamberlain for their eastern extension. The only other identifiable fossil from this formation is several teeth of the *Equus major* Dekay. This species is most abundant in the Eastern States, where the Equus beds have not been certainly identified; but it occurs also in the Equus bed of Nueces county, with other characteristic species of that epoch. The specimens of the two species named came from Wharton county.

II. UPPER CENOZOIC OF THE STAKED PLAINS.

In some remains of vertebrata, obtained by Mr. W. F. Cummins, from Crosby county, Texas, and sent me for determination by Mr. E. T. Dumble, State Geologist, four genera may be identified, and several others are indicated. The four genera are Equus, Mastodon, Creccoides g. n., and Testudo. They are enclosed in a white siliceous friable chalk, which Mr. Louis Woolman finds on examination to be highly diatomaceous. Professor C. Henry Kain had identified the following species: *Campylodiscus bicostatus* W. Smith; *Epithemia gibba* Ehr.; *E. zebra* Ehr ; *E. gibberula* var. *producta* Ehr.; *Navicula major* Ehr.; *N. viridis* Ehr.; *N. rostrata* Ehr.; *N. elliptica* var. *minutissima* Green; *Gomphonema clavatum* Ehr.; *Cymbella cistula*, Hemp.; *Fragillaria vivescens* Raffs var. The formation has been named the Blanco Can-

yon by Mr. W. F. Cummins of the Survey. (Report 1890, p. 190, without specific location in the Cenozoic series.)

The Mastodon is of the *M. angustidens* type, as indicated by the teeth, but there are not enough fragments preserved to render it clear whether they pertain to this species or some allied one. The Equus is allied to the *E. occidentalis* of Leidy, but the enamel plates are more simple than in that species, being the most simple known in the genus. I regard it as an undescribed species, and describe it below under the name of *Equus simplicidens*. A second species of horse is indicated, but an exact determination cannot be made without additional material. The tortoise is a terrestrial form, but there is not enough preserved for identification.

EQUUS SIMPLICIDENS COPE. Proceedings Am. Philos. Soc. 1892, p. 124.

This species is represented by one nearly entire superior molar of an adult, and one of a young animal, with characteristic fragments of two other superior molars, and several fragments of inferior molars. The size of the teeth is about that of the *E. occidentalis* and *E. caballus*. The internal column is of moderate anteroposterior extent, its posterior border marking the anterior third of the posterior lake. Its long diameter is considerably less than half that of the crown. A peculiarity found in two of the superior molars, but not in two others, is that the median dentinal connection between the external and median crescents is interrupted by the continuity of the enamel plates bordering the lakes from the one to the other. This arrangement is frequently seen in the large pm. 3, in the species of Equus, but does not occur in the other premolars and molars. It is a reversion to the condition seen in Anchitherium. A principal character of the species is seen in the extreme simplicity of the enamel borders of the lakes. They are without inflection, except the usual loop on the posterior inner border of the anterior lake, and this is simple and widely open at the base. At the point of junction of the median crescents (meta and paraconules), the usual loop of the internal enamel border is seen. The external median rib is narrowed and not flattened; the anterior rib is more flattened, especially at the present grinding face.

The species with which it is necessary to compare this species is the *Equus occidentalis* of Leidy. The enamel plates bordering the lakes in that species are always more complex, although they are simpler in it than in any other extinct species of North America. Even in the simplest forms (*e. g.*, that figured by Leidy in Vol. I, Report United States Geological Survey Tens., 1873, Plate XXXIII, Figures 1, 2) the lakes have anterior and posterior emarginations on the inner border, which are wanting in the present species.

The species is probably the oldest member of the genus Equus known from North American beds. It is the only species which was contemporary with a Mastodon with the *M. angustidens* type of molars. The simplicity of the enamel foldings is appropriate to this primitive period, as it approximates to the condition seen in many of the three-toed horses and the supposed one-toed *Hippidium spectans* Cope.* The size of the molars is about that of the modern horse, *E. caballus* L.

Observations.—The contemporaneity of this species of Equus with the Mastodon with molars of the *M. angustidens* type has considerable significance. The latter is characteristic of the Loup Fork horizon in North America, in which the genus Equus does not occur. The Equus beds, so named from the abundance of individuals of four species of Equus which they contain, have never produced a specimen of Mastodon allied to *M. angustidens* in North America.† The fact that the Equus of the Staked Plains is different from those of the Equus beds, adds to the indication furnished by the Mastodon that these beds do not belong to the Equus horizon; but the presence of the genus Equus is equally conclusive that they do not pertain to the Loup Fork. It is probable that the age of the beds is intermediate. They thus offer an interesting field for further research.

CRECCOIDES OSBORNII SHUFELDT. Proceedings of American Philosophical Society, 1892, p. 125.

Char. gen.—Only a fragment of a left tarsometatarsus represents this new genus and species of bird. It evidently belonged to some wader of about the proportions of a medium-sized heron, or to a form rather larger than the Floridan crane-like rail Aramus.

The specimen consists of about the superior moiety of the tarsometatarsus, and, in so far as it goes, appears to be perfect, with the exception of slight marginal abrasions of the summit of the bone and the almost complete fracturing off of the hypotarsial process. Superiorly, the intercondyloid prominence or tubercle is rounded and not especially conspicuous; the inner condyloid depression is more extensive than the outer one, and occupies a higher plane. In front the shaft is longitudinally excavated only above, the excavation gradually but soon disappearing as we pass down towards the distal extremity; and at the midpart of its continuity it is subcylindrical upon section. A short distance below the head of the bone are seen the usual anteroposterior perforating foramina, here three in number, two being lateral and below, with a mid one just above them. Immediately below these is a single, somewhat prominent tubercle for the insertion of the tendon of

*American Naturalist 1887, p. 1072.

†It is probable that the *Dibelodon shepardii* Leidy, which has molars of this type, occurs in the Equus beds of the valley of Mexico. Cfr. Cope, Proceedings of American Philosophical Society, May, 1884.

the *tibialis anticus* muscle. It occupies nearly a medial position upon the shaft. So far as can be ascertained from the imperfect hypotarsial process it would appear that it possessed originally a large, single, inner groove for tendons, with a plate-like projection to its outer side.

Char. specif.—Proximally, the tarsometatarsus is considerably excavated to the inner side of the hypotarsus at a point just below the summit. The outer muscular line is single and commences at the middle point of the margin of the outer condylar depression, passing from thence down the back of the shaft. The inner muscular line bifurcates proximally, then passes more obliquely backwards than the outer line, to finally pass parallel with the latter also down the back of the shaft.

MEASUREMENTS.

	Mm.
Greatest transverse width of proximal end	15
Greatest anteroposterior diameter of prox. end, not including hypotarsus	11
Distance from apex of intercondyloid tubercle to the tubercle for tib. ant. muscle	10
Vertical depth of hypotarsus	10
Transverse diameter of shaft near its middle	6

Remarks.—This fragment has been compared with the corresponding part of the skeleton in a great many kinds of birds. It was found to differ entirely from all larine, gallinaceous and raptorial types, while on the other hand it seemed to combine the characters of several various species of existing waders and allied groups. The writer compared it with numerous species of the genera Guara, Plegadis, Aramus, Rallus, Crex, Porzana, Ajaja, Tantalus, Botaurus, Ardea, Nycticorax, Grus and the Gallinules, Storks, etc.

For a skeleton of *Crex pratensis* I am indebted to Mr. F. E. Beddard, prosector of the Zoological Society of London, and for the loan of other material to the United States National Museum, as well as to Mr. F. A. Lucas, of that institution, for placing the same at my disposal. In the specimen under consideration, the Ralline characters appear to predominate, while more remotely we may see Ibis in its general form and outline. Apart from the question of size it, however, distinctly differs from the tarsometatarsus in such a form as *Aramus giganteus* in that the shaft is more cylindrical as it approaches its midportion, and, as has been said above does not show the anterolongitudinal excavation in that part. Moreover, in Aramus the hypotarsus exhibits *two* grooves for the passage of tendons, and the tubercle for the insertion of the *tibialis anticus* muscle is double. Essentially, it agrees with Aramus in the *general form* of its hypotarsus and in the direction of its lateral muscular ridges. In other particulars it exhibits both some minor differences and agreements with the corresponding bone in the skeletons of Crex and Rallus. Upon the whole the specimen would appear to have belonged to some large rail-like wader, now extinct.

The name of the genus I create to contain this form is composed o

the two Greek words, ——, a crake, and ——, resemblance. Its specific name is given it in honor of Prof. Henry F. Osborn, of Columbia College, New York, in recognition of his excellent work in paleontology for a number of years past.

The specimen was collected by Mr. W. F. Cummins, and the writer is indebted to Prof. E. D. Cope, for the opportunity of describing it.—*R. W. Shufeldt.*

TESTUDO TURGIDA. Proceedings of American Philosophical Society, 1892, page 127.

This species is represented by the greater part of a chelonite of about the size of the *Xerobates agassizii* of Arizona. It is remarkable for the remarkable depth of the dermal sutures and sculpture lines, and for the swollen character of the interspaces which separate both. The general shape is a short, wide oval, with steep to vertical margins.

The plastron is widely emarginate posteriorly, and the anal-femoral dermal sutures form a deep notch in the border. The anal scuta are oblique rhomboids, with equal and nearly parallel sides. The median longitudinal dermal suture is deep and wide, cutting half through the thickness of the plastron. It sends off a branch on each side bounding the gular plates in front. The part of the plastron enclosed in the latter forms two flattened cones appressed together, whose vertical diameter exceeds the transverse, and whose subconic apices are separated by a deep notch. The interclavicular bone is very large and is wide diamond-shaped, the anterior angle being larger than the posterior. The transverse humeropectoral suture is very deep, and is similar to the median longitudinal. The borders of the anterior lobe are strongly convex, with a chord only twice as long as the lateral border of the gular plates.

The nuchal bone has a strongly concave-emarginate border. On the posterior vertebral bones is a seat-like concavity, which is surrounded by a ridge which forms the greater part of a circle. The costal bones are unequally divided by the costal dermal sutures, which are very deep. Each costal scutum is divided into two areas, one of which is marked with ribs parallel to the vertebral axis at one extremity and a seat-shaped plane with a bordering ridge at the other, which is in some of the costals smaller and more swollen. The other half or part of the costal scutal area is swollen in the longitudinal direction, but not for its entire length. The marginal bones are massive and have a subacute border between the bridge and the median points. They are much deeper than long, and are deeply divided by the sutures which separate the dermal marginals. These grooves cut the margin into deep notches at some points and into shallower ones at others. The areas between these sutures are all swollen in the same way as the alternate parts of the costal plates.

MEASUREMENTS.

		Mm.
Length of plastron anterior to posterior angle of interclavicle		80
Width of plastron anterior to posterior angle of interclavicle		112
Length of interclavicle		40
Width of interclavicle		58
Thickness of interclavicle		11
Length of free lateral margin of gular plate		29
Width of base of both gular plates		45
Length of xiphiplastral bone		32
Width of xiphiplastral bone on anterior suture		53
Width of emargination of posterior lobe of plastron		50
Diameters of free marginal near bridge	anteroposterior	20
	vertical	34
	transverse below	25
Diameters of marginal of bridge	anteroposterior	29
	vertical	44
	transverse below	21
Diameters of penultimate vertebral bones	anteroposterior	17
	transverse	30

The American tortoise, which has produced gular areas somewhat like those of this species, is the *Testudo cultratus*, Cope, of the White River Neocene of Colorado. That species is, however, totally different in the dermal sutures of the usual character, flat marginals, etc., and the gular processes are not conic, but trihedral in form.

The specimen above described comes from Espuela near Dockum. The horizon is the same as that of Crosby county, i. e., the Blanco Canyon bed.

III. ON A MESOZOIC PYCUODONT.

MICRODUS DUMBLEII. Proceedings Amer. Philos. Soc., 1892, p. 128.

This species is represented by a splenial bone of the left side, which supports four and a half rows of teeth. The external two rows include small teeth with crowns which are either round or slightly transversely oval. The teeth of the third row are larger and the crowns are all transversely oval. The teeth of the fourth row are of unequal sizes, commencing anteriorly of about the same size as those of the third row. The third tooth from the front, as preserved, is much larger, but it is exceeded by the fourth; while the fifth is half as large again as the fourth. The sixth and last is a little smaller than the fifth. The teeth of the fifth row are as small as those of the first and second rows, and extend posteriorly to the anterior part of the fourth of the fourth row, and not beyond. The crowns of the teeth are perfectly smooth and without keel or depression.

		Mm.
Length of tooth series		17
Six teeth of external row		10
Six teeth of third row		11.5
Six teeth of fourth row		16.5
Diameters of fifth of fourth row	anteroposterior	3
	transverse	7

The horizon of this species is not exactly known, but it is probably Lower Cretaceous. It gives me much pleasure to dedicate it to Mr. E. T. Dumble, Director of the Geological Survey of Texas.

V. TRIASSIC OR DOCKUM BEDS.

The fossils from these beds present a general similarity to those obtained elsewhere in the Trias. Fragments of large Stegocephali are abundant, and Crocodilia of the Parasuchian group are still more so. Teeth like those of the Eastern Clepsysaurus and Zatomus also occur. The number of identifiable species is small, and the best preserved of these is a new representative of the genus Episcoposaurus Cope, already described, from the Triassic bed of New Mexico.*

EPISCOPOSAURUS HAPLOCERUS. Proceedings Amer. Philos. Soc., 1892, p. 129.

I refer to this species the following pieces which were found together by Mr. W. F. Cummins: A dorsal and probably two caudal vertebræ; a scapula of the right side; a few fragments of ribs, and almost thirty dermal bones. The generic characters and those of higher value may be first described.

The single dorsal vertebra is from the posterior part of the series. Its articular surfaces are shallowly concave. The neural arch is not entirely co-ossified, part of the internal surface being visible in the fracture, from which the neurapophysis has been broken. There is a rib-facet at each end. The smaller, which is longer than deep, is continuous at an open angle with the tubercular articulation of the short diapophysis. The other is longer than deep, lenticular in outline, and terminates acutely above. The scapula is massive, and the inferior extremity is thinned below and turned obliquely inwards. No mesoscapula. The coracoid facet is not large, and is separated by an angle from the glenoid cavity. The ribs are flat, not very wide, and have one subacute edge. The head of one is attached to the dorsal vertebra, above described. The capitular and articular surfaces are subequal and are separated by an angle. The dermal bones are thick and are united by suture, so as to form transverse bands across the body; but are not united in the anteroposterior direction. Some of them have median tuberosities, which are developed in others into horn-like spines. These four rows on the opposite side of the middle line not being symmetrical.

Char. specif.—The dorsal vetebra above referred to has the centrum slightly wider than deep. Its inferior surface is contracted on each side, and is slightly concave on the middle line. The surface is smooth. The diapophysis is robust, subtriangular in section, and it does not project freely beyond the centrum. The centrum of a caudal vertebra

* Proceedings Amer. Philos. Soc., 1887, p. 213.

with chevron facets is deeper than wide, and has a robust diapophysis, which springs principally from the centrum. The outline of the articular face is a hexagon elongate vertically. This is partly due to the broad truncation of the inferior face. Concavity of centrum slight.

MEASUREMENTS OF VERTEBRÆ AND RIBS.

		Mm.
Diameters of dorsal	anteroposterior	66
	vertical	64
	transverse	75
Diameters of caudal	anteroposterior	52
	vertical	59
	transverse	51
Vertical diameter of head of rib attached to dorsal, above mentioned		46
Transverse diameter of capitulum of rib attached to dorsal		26
Transverse diameter of shaft of another rib		40
Thickness of shaft of another rib		15

The section of the scapula is everywhere lenticular. It is robust, rather short, without much constriction at the base, and but a moderate expansion above. A distinct clavicular facet is not preserved. The incurvature of the inferior surface is most abrubt anteriorly, the angle there amounting almost to a tuberosity.

MEASUREMENTS OF SCAPULA.

		Mm.
Length on external face from superior border to line of superior edge of glenoid cavity		141
Diameters at narrowest part	anteroposterior	60
	transverse	32
Diameters glenoid cavity	vertical	52
	transverse	40

The *dermal bones* are subquadrate in form, and have sutures on two opposite sides and thin edges on the other opposite sides. The inferior surface is more or less concave from one sutural border to the other. They are all coarsely pitted, but the pits are reduced in size towards the edges in some of the plates. In many of the plates there is a prominent obtusely conic tuberosity placed unsymmetrically near the center or edge of the plate. This tuberosity is in some of the plates developed into a prominent spine or horn, which has an anteroposteriorly oval section. The surfaces of the tuberosities are punctate. These horns are placed on the sides, and probably not far from the median line, since they form with the adjacent tuber-bearing plates a strong angle, such as would be necessary to enclose the neural spines of the vertebral column. It is also not certain whether these spines were on the dorsal, cervical or caudal regions, or whether they were on all of them. The plates adjacent to those bearing spines are the most robust. The spines are gently curved, probably backwards.

MEASUREMENTS OF DERMAL PLATES.

		Mm.
Diameters of plate without knob	anteroposterior	90
	transverse	78
	vertical at suture	18
Diameters of plate with knob	anteroposterior	100
	transverse	70
	vertical at suture	37
Diameters of plate with spine	anteroposterior	115
	transverse (chord)	65
	vertical at suture	35
Elevation of spine of plate last measured from base (apex restored)		190
Diameters of spine at base	anteroposterior	95
	transverse	65
Diameters of spine 45 mm. below apex	anteroposterior	30
	transverse	20
Diameter of pits on flat bone		5
Diameter of pits on knobbed bone		9

In *comparison* with the only species of the genus known thus far, the *E. horridus*, the present species has the tuberosities and horns of a different shape. In that species the former are compressed and keel-like, and the horns are also compressed, having an edge in front and a triangular section. The individual which served as the basis of the description of the *E. horridus* is also of rather smaller size than the present one.

SHELLS COLLECTED IN THE SAND

OF

A DRY SALT LAKE NEAR EDDY, NEW MEXICO.

LIST AND NOTES

BY

DR. V. STERKI.

SHELLS COLLECTED

IN THE

SAND OF A DRY SALT LAKE NEAR EDDY, NEW MEXICO.

LIST AND NOTES BY DR. V. STERKI.

The specimens collected in the sands of a dry salt lake near Eddy, New Mexico, by Mr. W. F. Cummins, of the Texas Geological Survey, and kindly sent for examination by Mr. J. A. Singley, also of the Survey, are very interesting in several respects. They were very fragile and many of them broken more or less, yet no fragments of other forms could be found in the debris outside of those enumerated in the list. It was very difficult to handle and examine them, the more so since in most of them, especially the *Pupidæ*, the apertures were filled up with a chalky mass to remove which could not even be attempted. Some parts of the shells were also eroded by salt water (?), atmospheric influences, etc., especially the callous deposits, crests in the *Pupidæ*, also leaving in the palatal walls of *Pupa milium* and *Vertigo ovata* deeply impressed lines corresponding to the inside plicæ.

The species represented are the following, viz:

Hyalina minusculus, Binn. One example.

Vallonia costata, Mull, var. Numerous.

Vallonia, sp. indt. One example.

Pupa (*Pupilla*) *muscorum*, L. Rather numerous.

Pupa (*Bifidaria*) *procera*, Gould. Three examples.

Pupa (*Bifidaria*) *pentodon*, Say. Very probable. One example, immature.

Pupa (*Angustula*) *milium*, Gould. Quite numerous.

Vertigo ovata, Say. Sparingly.

Succinea avara, Say. Sparingly.

Succinea ovalis. Gould(?) One fragment.

Linnæa desidiosa, Say(?). A few examples.

Linnæa humilis, Say. Two or three examples.

Planorbis parvus, Say. A few.

Pisidium abditum, Hald. Some valves.

Besides these molluscs, there were about a dozen entire shells of one or two species of *Cypris* or *Cypridina* (an Ostracod crustacean) probably of comparatively recent origin.

The first impression on looking over these shells was one of surprise. They are in general northern species, or at least such as are found sparingly in the fauna of the southwest at this time. But, then, why

only these and not other forms also that are now almost everywhere found in company of those described? Some more, however, might be found if more material were at our disposition. On the other hand, there is amongst them not one of the characteristic forms now inhabiting that part of the country.

To judge of their geological age is impossible for me, but that could be ascertained (and probably has been) by the gentleman making the collection.

It would be of interest to have more of the material, and also to know whether there were any larger shells or fragments of such found in the locality.

But it must be said also that our knowledge is very limited concerning the recent molluscan fauna of that region. The valleys, as well as the mountains, where more conformity with the northern forms may be found, or remains of the glacial epoch possibly exist, of which the shells under consideration might be witnesses.

A few notes to the above list may not be amiss.

The specimen of *Hyalina minuscula* has a diameter of 2.1 m. and the spire is rather elevated.

The form of *Vallonia costata* represented here by numerous specimens, is different from the common one of Europe and northeastern North America; it is somewhat larger (2.5–2.3 m.), the spire is more elevated, the whorls are, in most specimens, half more in number and more gradually increasing, more convex above, and more densely striated. How far the striæ were corresponded by ribs of the epiconch in the fresh shell is impossible to tell, but their existence is very probable. The umbilicus is decidedly wider and especially so by the last half whorl receding periferically. With all these differences, I yet believe we have to regard the present form as a variety of *Costata* rather than as a different species.

There is one specimen of *Vallonia*, diameter 2.4 m., with more elevated spire, smaller whorls, finer striation, and a deep, regularly formed umbilicus. The aperture is comparatively smaller, somewhat less oblique (to the axis) and especially less tangential, its margins are only slightly averted and without any trace of a lip-thickening. Whether the example be mature or not is impossible to decide, and also whether it represents only an individual aberration of the foregoing or a different species; but the latter is decidedly more probable.

Pupa muscorum.—The typical form as far as recognizable, a parietal lamella is present in some, absent in other examples. The true *muscorum* is now living only in the northeast, hardly exceeding New York to the west or south. Among the different related forms from the mountainous west I have not seen a type.

Pupa procera is a species of the east and interior part of our country,* its most southwestern position being middle Texas, from where I have seen it in company with *P. hordeacea*, Gabb, and *P. hordeacella*, Pilsbry.

Limnæa desidiosa.—About ten small specimens, for the most part damaged, of a slender form, distinctly umbilicated, with well rounded, somewhat shouldered whorls and deeply impressed suture, can hardly be ranged under any other species, although, even when mature, they certainly were of small size.

Planorbis parvus.—Among the specimens, most of them very young, there were two with considerably narrower whorls. Yet I believe they rather represent a poorly developed local form than a different species.

Pisidium abditum.—While I range the valves examined under this head, it must be said that they differ somewhat in outline. A few have the posterior part distinctly truncated, in others the lateral teeth, especially the posterior, are short and high. The specimens are small and most of them young.

NEW PHILADELPHIA, Ohio, May, 1892.

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*See "The Nautilus," IV, p. 140.

REPORTS

ON

THE CRETACEOUS AREA

NORTH OF THE COLORADO RIVER.

I. THE BOSQUE DIVISION.
II. THE LAMPASAS-WILLIAMSON SECTION.

BY

J. A. TAFF.

REPORTS

ON THE

CRETACEOUS AREA NORTH OF THE COLORADO RIVER.

BY J. A. TAFF.

PREFACE.

While many treatises have been published concerning the Cretaceous system of Texas, including that part north of the Colorado river, none have dealt in detail with the stratigraphy. Not even has there been given a complete section of the rocks in their typical occurrence, and indeed, up to 1887, very little was known of the true relations of the two series, or of the separate divisions composing them.

The formation has not been studied elsewhere in the United States under conditions which exist here, and the consequence was that, worked as it was, almost exclusively in the light of paleontologic evidence, there had arisen some confusion of its true relations. The fauna was studied in a great measure apart from the stratigraphy, and from the fact that the fauna of the Texas series was almost entirely new in species, rock correlations made from it were very unsatisfactory.

So little attention was given to the stratigraphy, the unconformability between the upper and lower series was not even suspected, nor the existence of the great fault thought of, which almost transects the State along the contact of the two series.

The littoral or shallow water deposit at the beginning of the Upper Cretaceous era was misinterpreted, and that part occupied by the Lower Cross Timbers was considered to be Tertiary, because of its sandy beds and apparently more recent fauna and flora. At the same time that part of the formation which extends along Red River below Denison was correlated with a part of the basal sands of the Lower Cross Timbers, the Upper Cretaceous marl, Trinity sand at the base of the Lower Cretaceous, and with the Permian red beds and Tertiary of the Llano Estacado of Northwest Texas, and was called Lower Cretaceous.*

The publications of Wm. Kennedy, Dr. Ferd Roemer, B. F. Shumard, and other scientific explorers, were of great value to the State, but with the exception of the highly valuable paleontologic works of Drs. Roemer and Shumard, there is little that contributes knowledge of scientific importance.

* "Partial Report on the Geology of Western Texas," p. 20 *et seq.*, by Geo. G. Shumard. Also, "Observations on the Cretaceous Strata," B. F. Shumard, Transactions Academy of Sciences, St. Louis, pp 588–590 and other publications.

All the information published concerning the geology of Texas north of the Colorado, since 1886, gives merely an outline of the geology, the occurrence and general development of the beds with their most characteristic fossils.

GENERAL GEOLOGIC AND PETROGRAPHIC FEATURES OF THE REGION.

NOMENCLATURE.—The terms used by geologists to represent the groups and systems of groups of the rocks of the earth's crust have been in the main fixed. The terms used to represent series of systems, divisions of series and beds of divisions are dependent for their names upon their character and environments. Names to which there are no objections are exceedingly difficult to select, because geologists working in different fields see different developments of the same beds. A deposit of deep-sea limestone, as it is traced from the interior of the former sea to its old shore-line, will diminish in thickness, or be replaced by varying beds of sand or clay, and as a bed of rock is traced for a long distance parallel to the former shore-line, its character varies with the conditions and nature of the material from which it was derived.

Where the country rocks are hard, or crystaline, rivers and creeks transport comparatively little sand or silt from the land into the sea. In such localities the sea is often deep not far distant from the shore, and the conditions are suitable for the deposition of clay and lime sediments. At other localities along the same seashore line, where the country rocks are soft sands and clays, the rivers carry vast quantities of mud and sand out to sea, forming new beds of sand and clay to be consolidated into rocks similar to those on the high land. In these deep sea and shallow water formations the shells of mollusks and the skeletons of other animals which inhabit the sea and land show that this is a continuous bed, though the rock changes from lime to clay or sand. A bed of limestone in the lower division of the Lower Cretaceous occurring in the western part of Travis county, where the shore of the sea in which it was formed was but a few miles to the west, if traced northward along its outcrop into Parker, Wise and Montague counties, will be seen to change from the limestone in the first place to an arenaceous marly lime rock, and then further on into a calcareous sand. If we examine the rocks along which the shore of this Cretaceous sea once existed, we find, opposite the near shore limestone, hard crystaline limestone, schist and granite, forming a mountainous, rugged coast; but further north, where the sands of the same bed were formed, the country rocks are comparatively soft sands and clays.

Since, therefore, beds and rocks change in composition, and vary in extent of development from one part of a district to another, and since a bed, thick and without much variation in composition in one place,

thins in another and forms local subdivisions, it is necessary to exercise great care in naming divisions and beds, lest it be found afterwards that the names do not apply in the locality of their typical development, or lest it be found that the name given really applies only to a part when it should apply to the whole division or bed.

It is also fruitful of much trouble to apply the distinction of "bed" to certain local subdivisions of rock that are clearly seen to form parts of a homogeneous whole, which have been as a whole correctly distinguished as a bed. In many cases this was inevitable on account of partial studies of rocks in local areas.

Certain names have been applied to the divisions of the Texas Cretaceous, because of some lithologic feature of a subdivision, or on account of a fossil which may abound in one or more of the beds of the division. For instance, the term "chalk," when applied to a division of rock which is not chalky in general, and which in some localities has no chalk, is misleading, and should not be adopted.

For these reasons, wherever practicable, such names are dropped in this report, and abstract names that have been applied are used in their stead.

The following table of divisions and subdivisions, in descending order, with names of authors, is as full as can be given:

II. UPPER CRETACEOUS.

North Texas.	*South Texas.*
Wanting.	Eagle Pass division (4).*
Wanting.	4. Escondido (4).†
Wanting.	3. Coal series (4).
Wanting.	2. San Miguel (4).
dd. Blue marl.	1. Upson clay (4).
cc. Austin limestone (1).‡	Pinto limestone (4).
bb. Eagle Ford shale (3).	Val Verde flags (4).
aa. Red River (1).§	

(1) B. F. Shumard. (2) Dr. Ferd. Roemer. (3) R. T. Hill. (4) E. T. Dumble. (5) J. A. Taff.

* Applied to the division by Mr. E. T. Dumble in his Notes on the Geology of the Valley of the Middle Rio Grande, published in the Bulletin of the Geological Society of America, Vol. III., pp. 219–230.

† Extensive thickness of sand and marl deposits occur here in the Escondido and Coal Series beds which are considered to be above any known Cretaceous terranes north of the Colorado river.

‡ Named by Dr. B. F. Shumard in Transactions St. Louis Academy of Sciences, 1860. "Dallas Limestone," "Rocky Comfort Chalk," "Austin-Dallas Chalk" and "Austin Chalk," of R. T. Hill.

§ "Lower Cross Timbers Sands" of Hill. Has its greatest development along Red River through Grayson, Fannin, Lamar and Red River counties.

I. LOWER CRETACEOUS.

Washita Division.

m. Vola limestone (3).
l. Arietina clay.
k. Denison (3).
j. Fort Worth (3).

Fredericksburg Division (2).

i. Kiamitia clay (3).
h. Austin marble (3).
g. Flag limestone (3).
f. Caprina limestone (1).
e. Comanche Peak (1).
d. Texana.

Bosque Division (5).

c. Paluxy sand (3).
b. Glen Rose (Alternating) bed (3).
a. Trinity sand (3).*

BRIEF OUTLINE OF THE SYSTEM NORTH OF COLORADO RIVER.

LOWER CRETACEOUS (COMANCHE) SERIES.

As a whole this series is a formation of limestone, though siliceous materials enter into its composition, and in some parts form the prevailing elements of rock-making materials.

BOSQUE DIVISION.

Beginning at the base with the Trinity sand, there are heavy deposits of nearly pure sand, gravel, and in some cases conglomerates of cobblestone, showing in their false-bedding and alternating structure of coarse and fine materials a history of rapid current and strong wave action along shore, followed by slighter current and weaker wave action. Near the top of these littoral deposits are records of slow deposits in fine sand and limy silt, which has been thrown down off-shore as the land subsided and as the shore-line moved further up.

North of the Trinity river the bands of limestone and lenticular bands of calcareous clay of the Glen Rose (Alternating) bed succeed the littorals or the base of the system. These layers of lime and marly clay thicken into extensive beds of lime marl to the south and southwest between the Trinity and Colorado rivers. In these alternating beds of lime and lime marls there are recorded evidences of changing conditions in the deposits.

(1) B. F. Shumard. (2) Dr. Ferd Roemer. (3) R. T. Hill. (4) E. T. Dumble. (5) J. A. Taff.

*Published as "Dinosaur," "Basal," "Upper Cross Timbers" and "Trinity Sand," at various times, by Mr. R. T. Hill. It was originally given the prominence of a division, but later investigations by the Survey have proved it to be one of three beds of a united division.

Layers of calcareous sand are succeeded by layers of arenaceous lime marl. Marl beds are followed by thick and thin beds of hard limestone and by chalky foraminiferal limestone near the center of the formation. Then in a general way the ascending order is reversed until sand is again brought to view. This latter condition exists only north of the Leon river, and south of that stream arenaceous and oolitic limestone continues upward, usurping the position occupied by the second sand zone further north.

Multitudinous fossils of numerous genera and species abound in these alternating layers. The majority of these species do not pass to higher beds, though many do. With but few exceptions all of these fossils occur as casts which take the form of the inside of the shells, for which reason their identification is difficult.

A small fragile variety of *Exogyra texana*, Roemer, which occurs at the base of the Fredericksburg division, was found near the middle and at the summit of the Glen Rose series on the Bosque river, and one hundred feet beneath the summit of the bed on the Colorado river.

As the Alternating beds diminish northward from the Leon river they are succeeded by an ever increasing bed of sand, called the Paluxy sand, which blends at its upper border with bands of dimension shell limestone and layers of marly sand. Between the Leon and Trinity rivers this sand rests upon Glen Rose lime and marl. North of the Trinity river, except for a few miles in the southern part of Wise county, the Paluxy sands rest upon the Trinity bed without a perceptible break in the stratigraphy. The character of the upper portion of the Trinity and the Paluxy sand is similar in deposit, structure and fossil remains. Both beds were probably formed under the same conditions and had the same origin. A pebbly zone, which follows the Paleozoic floor at the base of the Trinity, is not present in the Paluxy, for the reason that only the basal zone beds of the Trinity were shore deposits, and these fine sands were sorted and deposited near shore by weak currents and waves.

Logs and fragments of silicified wood, lignite and silicified beds of leaves, occur in abundance in the Trinity and Paluxy sands. These were drifted as wood from the rivers out into the sea, where they sank and were covered by the sand. Where the sand surrounding the wood was porous, silicified wood was formed; but where the wood was enveloped in clay or argillaceous sand, it became lignite.

FREDERICKSBURG DIVISION.

This is pre-eminently the lime formation of the whole Cretaceous system. Though there are indications of shallow water action in the ripple marked and slightly siliceous flagstones, yet the body of the limestone is quite pure and free from sand.

The Texana bed begins with an arenaceous marl at the upper edge

of the Paluxy sand, north of Lampasas county, and continues upward through horizons of marly chalky lime* and massive shell limestone to a massive chalky lime at the summit. Between the Colorado and Leon rivers the Texana bed rests upon the alternating limestone of the Glen Rose bed. Opposite Austin it is ten or fifteen feet thick; at Bachelor's Peak, in Burnet county, it is seventy or eighty feet; in Bosque and Parker counties it is ninety to one hundred and twenty-five feet; from the Trinity river northward to Red River it rapidly diminishes from more than one hundred feet to a narrow band of but a few feet.

On the approach of the chalky lime of the Comanche Peak bed, following the *Gryphaea pitcheri*, which prevails in such numbers and in such beauty of form in the center of the bed, the Texana bed dwindles to a small size and disappears. The *Exogyra texana* continues further up into the chalky lime where it attains its greatest thickness. The line of parting between the Texana and Comanche Peak beds is not of stratigraphic importance. The marly lime of the one grades almost imperceptibly into the chalky lime of the other. The limit of occurrence of the *Exogyra texana* marks the border between them.

With the Comanche bed there is a culmination of the chalky limestone begun in the Texana bed. From base to top it is massive and homogeneous in structure, and has clearly defined stratification planes. It weathers readily into conchoidal fragments and then into a chalky marl. The bed is one hundred feet thick between the Colorado and Brazos rivers, where it ends at the top in from ten to fifteen feet of a more persistent chalky lime. On hill slopes and as the capping rock of the buttes it stands out in a well defined bluff. North of the Brazos river this massive bed of chalky lime dwindles to a narrow band at the Indian Territory line.

The Caprina bed succeeds the Comanche Peak limestone with but little lithologic change in the strata. The magnificent and unique *Rudistes* and *Chamidae* fauna and the rich flint deposits peculiarize this bed. In Williamson county there are four grades of flints which range from very near the base to the summit of the bed, which has a thickness of nearly one hundred and sixty feet. South of this place the bed becomes much thicker even than this, as the writer observed on the Nueces river. Toward the north it diminishes in thickness until it disappears, as far as is known, between the Brazos and Trinity rivers.

The flaggy limestone follows upon the chalky and flinty lime deposits of the Caprina bed, and presents a series of thin ripple-marked and thick flaggy limestone, barren of any fossil fauna so far as is at present known. The occurrence of these flags is not known beyond a limited

*Some of the local marly strata which occur in the bed in its greatest development have been designated as the Walnut clays. Bulletin of the Geological Society of America, Vol. II, p. 512.

range. They have been seen at Austin, at Round Rock and at Georgetown, where they have a thickness of from ten to fifteen feet.

The Austin marble* is a narrow zone of masses of fossil *Rudistes* and *Chamidæ*, and follows upon the flag limestone. It is the culminating zone for the numerous *Caprina* and *Caprotina* forms which appear in the Caprina bed below. Like the flag limestone it is unknown beyond a limited range of occurrence. It has been seen at Austin, Round Rock, and along the Balcones escarpment between Austin and San Antonio. It has not been found to exceed ten feet in thickness at any locality observed.

There is no reason on stratigraphic grounds why the Austin marble should be placed in the Washita division, and I have placed this bed in the Fredericksburg division because of the faunal relation it bears to other beds of this division. It is the culminating bed of the magnificent *Hippurite* and *Chamidæ* fauna of the Lower Cretaceous.

The Kiamitia clay † has been studied but little. Sections were made of it at Goodland, where it was found to be one hundred and twenty feet thick. It was estimated to be nearly one hundred feet thick in the valley of Red River north of Denison. It was examined also in the Trinity river valley eight miles west of Fort Worth.

Dark greenish blue laminated clays with beds of limestone, from a few inches to a foot thick, composed almost wholly of the Gryphæa and Ammonite shells, compose the rock.

At Round Rock there is at the base of the Fort Worth limestone a few feet of argillaceous shell limestone which contains the fauna of the Kiamitia clay.

This bed is evidently a wedge of clay and shell lime, beginning on Red River with one hundred to one hundred and twenty feet, and ending or passing Round Rock as a thin band of argillaceous limestone.

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*Heretofore the Austin marble and the flag limestone have been placed at the lower limit of and considered to be the border bed of the Washita division. See Bulletin No. 4, Geological Survey of Texas, p. 21. In the same Bulletin, pages 25 to 46 the flag limestone (Barren Flags of that paper) is transferred to the top of the Fredericksburg division. In other publications also the same author has considered the Austin marble as belonging to the Washita division. Of the fauna occurring in the bed not a single form, so far as we know at present, is known to occur above it, while every genus and species appears in one or the other of the two divisions below the Washita.

† Described in Bulletin of Geological Society of America, Vol. 2, p. 512. At all the localities examined by the writer there was no variation in the bed except in thickness. A decided Fredericksburg Ammonite, *A. acutocarinatus*, occurs with the Gryphæa form *G. forniculata*. It contains no Washita fossils as far as is known. Along the valley of the Brazos and Noland river individual fossils of *Exogyra texana* and other Fredericksburg fossils occur in the Kiamitia clay where it is fifteen to twenty feet thick.

WASHITA DIVISION.

The Washita formation brings to view an almost complete change of form and character of stratigraphy from that of the Fredericksburg below. The chalky and smooth flaggy beds of the Fredericksburg give place to earthy and marly layers of shell limestone and lime marl rarely becoming chalky.

The Fort Worth limestone carries an abundant and varied fossil fauna of Ammonites, Echinoids, Ostrea, Pecten, Terebratula and Nautili, occurring in the greatest profusion, in many places forming masses of rock. An excellent section is displayed along the San Gabriel below Georgetown, and there is an exposure between Austin and the Balcones fault three miles to the west along the Colorado river. As the beds are traced north from the Colorado river to Red River lines of demarcation between them become more clearly drawn.

The basal Ammonite zone remains a thick-bedded chalky limestone, while the medial Gryphæa zone becomes more arenaceous and shaly until in many places it loses the characteristics of a limestone. The upper *Ostrea carinata* and Terebratula zones become more shaly and marly than the same bands in the Colorado region, and blend with the *Ostrea quadriplicata* zone at the base of the Denison beds. The whole subdivision, in its northern extension, shows fluctuating and near-shore deposits, after the basal Ammonites zone is passed, until a shore deposit is reached in the Denison beds.

The thickness of the Fort Worth limestone varies but little from one hundred and fifty feet through its extent from Central to Northern Texas.

The Denison bed has been studied but little, and its outlines have not been traced except in a limited area. Its greatest development in Texas is in the Red River valley in Grayson and Cooke counties. South of Cooke county the outcrop of the Red River sand bed conceals the rocks of the Denison bed except at occasional points where erosion along river valleys has removed the sand.

The Denison bed crops out over a distance of one mile parallel with the dip of the strata north of Denison. From base to top the rocks are sandy clays, arenaceous lime and sands, friable except occasional fissile indurated flagstones, arenaceous lime and ferruginous nodules.

The bed begins at the base with a narrow zone of marly lime containing great numbers of *Ostrea quadriplicata* associated with *Gryphæa washitaensis* and *Cyprimeria crassa*. Fifty feet beneath the summit there is a band of arenaceous shell limestone one foot thick, which contains very many *Ostrea quadriplicata*. Above this zone fifty feet of nearly pure sand is found comprising strata of false-bedded sand with clay fragments interspersed, succeeded abruptly by thick beds of *Exogyra arietina* limestone.

This whole bed is nearly one hundred and forty feet thick, and con-

tains a very rich moluscan fauna. Its occurrence is not known as far south as the Brazos river.

The *Exogyra arietina* clay is the most peculiar deposit in the whole of the Texas Cretaceous. The occurrence of a continuous bed of clay from the Trinity river to the Rio Grande, a distance of nearly five hundred miles, of almost unvarying character, eighty to one hundred feet thick, and bordered on either side by thick beds of limestone, is a geologic feature worthy of note.

From the Brazos to the Red River this bed is partially concealed by the overlap of the Red River sand bed. On the north bank of the Brazos, in western McLennan county, the clay is seventy feet thick.

Along the valley of the Red River all that is seen of the *Exogyra arietina* bed is fifteen or twenty feet of heavily bedded limestone, which contains very many individuals of the characteristic fossil, and which is bordered below by the Denison sand bed and above by the sands of the Red River division.

Whether the Denison bed bears any nearer relation to the Arietina bed than merely a contact rock cannot at present be told. They bear no known fossil in common, except that the *Ostrea quadriplicata* occurs at the basal contact of the *Exogyra arietina* limestone in the bluffs of a run in the east side of the city of Denison.

VOLA LIMESTONE.—The Vola limestone represents the closing period of Lower Cretaceous sedimentation in Central and Southern Texas. This bed is ninety to one hundred feet thick on the Nueces river in Uvalde county, eighty feet thick on the Colorado river at Austin, and one to two feet thick on the south side of the Brazos river valley, near Bosqueville, in McLennan county.

North of the Brazos river the overlap of the beds of the Red River division conceals this bed if it exists there at all. From its most northerly extension it continues south, overlain everywhere by the Eagle Ford division, which is the lowest division of the Upper Cretaceous south of the Brazos river.

The characteristic fossil of this bed is the *Pecten* (*Vola*) *Roemeri* (Hill), from which the bed has been named.

UPPER CRETACEOUS SERIES.

The Upper Cretaceous of North and Central Texas, as a whole, may be classed as a marl. North of the Brazos only do the basal rocks partake of the nature of sandstone. Exclusive of this narrow area at the base of the Upper Cretaceous, occupied by the Lower Cross Timbers, the prevailing rock elements are clay, lime and sand, in the order given. Though these rocks vary in color, durability, amount of organic matter, relative quantity of clay, lime and sand, they may all, nevertheless, be justly classed as a marl. With the exception of local indurations and

nodular segregations these beds are all comparatively friable, yielding rocks.

The Red River division represents the littoral and shore deposits of the Upper Cretaceous. It consists of sands and sandy clays, lignite and lignitic clay shales, and (rarely) arenaceous shell limestone, which rest with unconformability upon the upper beds of the Washita division between the Brazos and Red rivers.

The beds of the Red River division diminish along their exposure toward the south from Red River, and finally disappear, or more probably grade into the flaggy clay shale and laminated clay of the Eagle Ford shale near the Brazos river.

The area occupied by these sands was a land area part of the time, during the mid-Cretaceous elevation and depression, and the Lower Cretaceous rocks were eroded and deposited as Upper Cretaceous material. South of the South Bosque river the clay or flaggy limestone of the Eagle Ford shale, or Val Verde flags of the Rio Grande region, rests in conformability upon the Vola limestone.

North of the Trinity river the line of parting between these sands and the overlying Eagle Ford shale is not clearly drawn lithologically, the gradation from one to the other being so gradual as to be hardly perceptible.

The Eagle Ford shale succeeds the Red River sand bed north of the Brazos river. Its greatest development is along the bed of the Red River, where it has a thickness of nearly six hundred feet. Coming south, this division diminishes gradually to about thirty feet at Austin.

Along the contact of the Upper and Lower Cretaceous, from Red River to Rio Grande, there is an unconformability only between the Brazos and Red rivers. South of the Brazos river the clay or flaggy limestone of the Eagle Ford shale or Val Verde flag division rests in conformability upon the Vola limestone and represents the off-shore deposits, equivalent to the Red River and Eagle Ford divisions in North Texas. That there is a representative of the Red River sand in the lower layers of the Eagle Ford shale south of the Brazos river is evident when it is known that the sands thin out toward the south, becoming more argillaceous, until they give place to clays and chalky flagstones; and it is true, also, that for every littoral deposit, however extensive, there is an off-shore and deep sea deposit, however diminished in thickness.

The Austin limestone succeeds the Eagle Ford shale, with a development of strata reaching nearly six hundred feet in thickness, north of the Colorado river. South of the Colorado, however, this division increases to great thicknesses* in the valley of the Rio Grande.

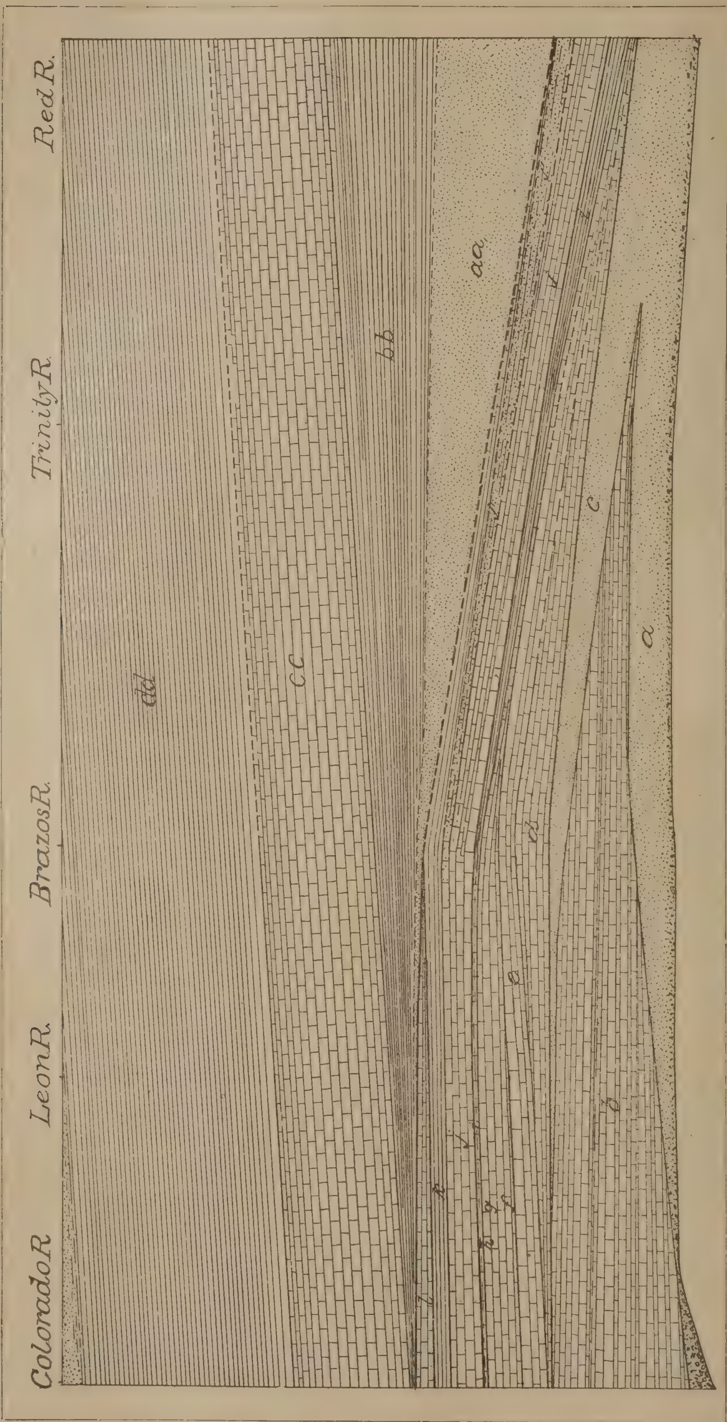
The discussion of the Austin limestone in Williamson county will

*See "Notes on the Geology of the Valley of the Middle Rio Grande," by E. T. Dumble.

apply to this division north of the Colorado river as far as is at present known.

The Blue Marl is the final division of the Cretaceous system in Texas. It presents a series of beds remarkable for their persistency and homogeneity of deposits. The Austin limestone ends in a chalky lime marl, which grades gradually into the Blue Marl. This marl continues upward for nearly one thousand feet with but little lithologic or faunal change. The body of this deposit, from the base almost to the top, occurs as a continuous deposit from the Colorado to Red River. The upper layers, however, show slight changes northward from the Colorado. In Navarro county the upper arenaceous or glauconitic bed is nearly five hundred feet thick. Still further north, near Red River in Lamar county, thin limestone strata appear in the upper beds, and Tertiary strata lap over on the upper beds of the Blue Marl northward along the contact. In the valley of the Rio Grande this division has a development of many hundred feet beyond that of any portion of North Texas. A glance at Plate VIII will show the true stratigraphic succession of rocks of the Cretaceous system north of the Colorado river as described briefly above.

PLATE VIII.



DIAGRAMMATIC SECTION OF THE CRETACEOUS SYSTEM ALONG THE STRIKE FROM COLORADO TO RED RIVER.

a. Trinity sand. b. Glen Rose (Alternating) bed. c. Paluxy sand. d. Texana bed. e. Comanche Peak bed. f. Caprina bed. g. Flag limestone. h. Austin marble. i. Kiamitia clay. j. Fort Worth limestone. k. Arietina clay. l. Vola limestone. aa. Red River (Dakota) division. bb. Eagle Ford shale division. cc. Austin limestone division. dd. Blue Marl division. Vertical scale, 1 inch=1000 feet.

I. THE BOSQUE DIVISION.

INTRODUCTION.

The Bosque, or lowest division of the Lower Cretaceous of Texas, has been formed to bring together three beds which have hitherto been placed in separate divisions, but which, for reasons that will appear as the details are brought out, must be considered and treated as one continuous series of deposits from the Paleozoic upward to the Fredericksburg. These three beds are:

1. Paluxy sand.
2. Glen Rose (Alternating) beds.
3. Trinity sands.

This decision has been arrived at only after a most careful study of the entire section of the division at typical localities, followed by close examination of the beds in detail.

The Bosque division is succeeded by rocks more homogeneous in structure and more persistent in nature, viz: the Texana bed of the Fredericksburg division. These superimposed rocks rest upon the medial Glen Rose bed at the Colorado river; but further north, on the Leon river, they pass upon the Paluxy sands, and so continue to the Indian Territory line in Cooke county. The contact line between the Bosque division and the succeeding divisions of the Fredericksburg has been accurately and continuously located north of the Brazos river, and many points have been located upon it south of the Brazos. The location of the line will be an easy matter from a simple description. South of the extension of the Paluxy sand, there is a chalky, crumbling limestone, which is to a great extent barren of vegetation and generally forms the base of an escarpment. In this limestone there are always present very many fossils of *Gryphæa pitcheri*, a hook-beaked oyster, one to three inches in length. Associated with this fossil is *Exogyra texana*, a flat, nearly eliptical, ostrean form. The lowest limit of these fossils marks the upper limit of the Bosque division.

Long arms of Texana and Caprina beds extend from the main body of the Fredericksburg on the east far toward the west along the dividing ridges, or water-sheds, between the principal streams, often to the western border of the main Cretaceous area. On account of the peculiar topography of the Trinity, Alternating and Paluxy beds, this contact line is exceedingly tortuous. It passes from the river beds on the east upward toward the west, around the deep ravines and canyons of the tributaries that have been cut by headwater erosion, back toward the center of the narrow dividing plateaus or ridges to its extreme western limit, and then around eastward again to the base of the next river valley. This feature of the contact line is well illustrated in the

Colorado section, Plate IX, which is drawn parallel to the Colorado basin on its north side, from the Paleozoic to the Upper Cretaceous, across the valleys of some of the tributaries of the Colorado river, viz: Hickory, Cow, Post Oak, Sandy, Cypress and Bull creeks. At d, d, d, along the heavily dotted line, the contact of the Fredericksburg division is seen to touch the tops of the dividing ridges between the creek valleys. From point at d, west of Cow creek, the contact passes around the head of each creek in a broken or continuous line, and finally appears at its most easterly extension at Mount Barker, where it is abruptly cut off and thrown down by the Balcones fault. From the same point d, west of Cow creek, the contact continues in the same tortuous line through Burnet and Williamson counties to the San Gabriel river, twelve miles above Georgetown. Thus it continues northward, from valley to valley, to the Indian Territory. North of the Lampasas river, the eastern limit of the Paluxy sands marks the Fredericksburg-Bosque contact. These sands are occupied by a narrow belt of timber extending from the Lampasas river to the southern part of Wise county, where they join the main bed of the Upper Cross Timbers.

TRINITY SAND.

GEOGRAPHICAL DISTRIBUTION.—Where the Trinity sand is exposed north of the Colorado river, it rests in unconformability upon Paleozoic rocks. Above it comes in contact in complete or partial conformability with harder rocks, or rocks which are like it in character and which belong to the same geologic series. Where the superimposed strata are harder than the sand, a decided escarpment is formed by the rapid breaking down of the rocks over the friable yielding sand. Where this is the case, the contact of the sand and its overlying bed is clearly marked, and can be readily and accurately located.

Such is not the case, however, at the base of the sand, where the harder rocks are below. In the valleys of the larger streams crossing the Trinity sand toward the southeast, and where erosion is very rapid, the contact of the sand with the Paleozoic rocks is easily discerned; but where these conditions are not present, the sands spread out over the edge of the irregular base level in attenuated sheets and remnant areas obscuring actual contacts.

The basal contact of the Trinity sand or conglomerate crosses the Colorado river at the Travis-Burnet county line. The conglomerate rests upon Carboniferous clay, shales and flaggy sandstones. Carboniferous rocks continue beneath the Trinity border, in a northerly direction, very near the intersection of the Austin-Burnet road and Hairston creek, where they give place to pre-Carboniferous limestone. These limestones continue as the Paleozoic contact-rock from Hairston creek northeastward by way of Burnet to Spring creek, about four miles west-

northwest of Burnet. Here hard pre-Carboniferous sandstones succeed the limestone beneath the Trinity, and so continue northward to the point where the contact crosses Morgan creek, south of Dobyville. Pre-Carboniferous limestone occurs again at Morgan's creek, and underlies the sand to the Trinity-Paleozoic contact, where it crosses the Burnet-Lampasas county line nearly due south of Nix, Lampasas county. From this point Carboniferous rocks persist beneath the Trinity sand across Lampasas county, one mile west of Nix, and thence nearly parallel with the Gulf, Colorado and Santa Fe Railway to Williams' ranch in Mills county. Thence the contact crosses into Brown county and crosses the Gulf, Colorado and Santa Fe Railway very near Ricker. From Ricker it continues nearly on a straight line to Clio. Beyond Clio, through Brown county, the southeastern portion of Callahan county, and northern Comanche county, there are large areas of undefined Trinity sand. Beginning again in northern Comanche county, the contact line passes northward through the following points:

Houston and Texas Central Railway four miles west of De Leon; Desdemonia, Eastland county; Twin Mountain, in northeastern Erath county, very near southeast corner of Palo Pinto county; Brazos river, very near south line of Parker county, at mouth of Kickapoo creek; Hiner Postoffice, south Parker county; Texas and Pacific Railway, nearly four miles east of Millsap; one and one-half miles west of Anthon; Whitt-Weatherford road one and one-half miles from Whitt, Parker county; Gibtown, Jack county; Willow Point, Wise county; two miles south of Bridgeport; Trinity river at the mouth of Sandy creek; Sandy creek due west of Decatur; Fort Worth and Denver Railway one mile west of Alvord, Wise county; very near Denver, Montague and Bonita, Montague county; and Red River north of Bulcher Postoffice, Cooke county.

On account of the irregular surface of the Paleozoic rocks, upon which the Trinity sand rests, and on account of the varied erosion of the many streams that pass across it with the dip of the rocks, the contact line marks a very tortuous course. So much so that it is not expedient to locate it by description. It is traced in detail, however, on the general map accompanying the First Annual Report, upon which all the divisions of the Cretaceous traced in the field are shown. Between the main Cretaceous area and the Staked Plains there are many remnantal areas or islands of Cretaceous rocks of various sizes left by erosion as table lands, buttes, and "sand-roughs." All of these with the exception of some undefinable remnants of loose sands, have been quite accurately located by actual surveys, and their locations are shown upon the map.

The upper limit or western border of the Trinity sand runs nearly parallel with the basal or western line across Travis, Burnet, Lampasas and Brown counties. The width of the sand depends upon its topog-

raphy, which is governed by the heavy beds of Glen Rose and Comanche Peak limestone. These limestones extend for the most part to within from one-fourth of a mile to two miles of the western border in wall-like escarpments which overlook the sand. Hence the surface is a stiffly inclined plane from the base of the limestone bluffs down to the Paleozoic border. In approaching the north line of Brown county, the width and thickness is found to be greatly increased, and the Comanche Peak escarpment has been moved away from the Trinity border by the interposition of the Paluxy sands, leaving the Glen Rose limestone and marls, which have much decreased in thickness. From the northwest corner of Comanche county, which is also the northeast corner of Brown county, the eastern limit passes down the Leon river valley by Comanche to very near the junction of the north and south forks of Leon river. From the Leon river the line continues subparallel to the Paleozoic contact through Dublin, Erath county; near Hiner, two miles west of Lambert and Springtown, Parker county, and Cottondale, Wise county. This contact crosses the Fort Worth and Denver Railway four miles northwest of Decatur. At this point the Trinity and Paluxy sands blend, but beyond this point, the summit of the Trinity sand cannot be determined by stratigraphic, lithologic, or paleontologic evidence. Opposite Decatur the parting between the two beds of sand is nearly midway between the base of the Fredericksburg division and the Trinity-Paleozoic contact, and is believed to hold the relative position through the northern portion of Wise and Montague counties.

A peninsula-like extension of sand, with limestone capped table lands and buttes, extends from the northwestern portion of Comanche county in a northerly direction across southern Eastland, northern Brown, and southeastern Callahan counties. The sand extends fully two hundred square miles in these counties.

From Comanche county northward to Red River, the average width of the Trinity sand is about three miles. The areal extent of the whole of the Trinity along the western border of the main Cretaceous and north of the Colorado river cannot be, by the lowest estimate, less than twelve hundred square miles.

TRINITY INLIERS, AREAS OF EROSION.—The dip of the rocks toward the southeast is little more than the grade of the country or the fall of the rivers which run approximately with the dip, hence the sands are exposed far down the sides and bases of the valleys, until the limestones occurring above them are brought to the river beds.

Some of the creeks and rivers that have their source within the main Cretaceous area near the eastern boundary of the Trinity have cut down into the sand by their rapid erosion, yet they are not able to maintain their position on the sand because of the two rapid dips of the rock, which carries them down to the stream beds again. By this

process of erosion, depressed islands of Trinity sands have been formed in the interior of the Glen Rose, or Fredericksburg limestones.

Such is the case in the region of the Lampasas, Paluxy and Bosque rivers, and other small streams. In the vicinity of Lampasas town, where the Trinity is thin, the Sulphur Fork of the Lampasas river has eroded not only into the Trinity, but through it, and is now upon a Carboniferous bed, and the Trinity conglomerate forms a border around the edge of the Paleozoic basin as described in the Lampasas–Williamson section.

The Paluxy valley, in Erath, Hood and Somervell counties presents an excellent illustration of a Trinity inlier. The Paluxy has its source upon the Glen Rose limestone, and by its erosion has cut out a magnificent valley and exposed the Trinity sand for about twenty miles, from Morgan's Mill, Erath county, to near Glen Rose, Somervell county, and from side to side of the valley; while at the same time it has formed a most fertile artesian well area.

In some cases these streams, which have a southeastward flow, by their headwater erosion have cut across the Trinity-Glen Rose border, stolen finally the drainage of other creeks, and still hold their sources in the Trinity sand.

THICKNESS AND CHARACTER.—The Trinity sand varies in thickness from nearly one hundred feet at the Colorado river, in the southeast corner of Burnet county, to a comparatively thin band of limestone conglomerate, where the contact crosses the north line of the county. As before stated, the areal extent of the Trinity across the county is small. Being composed principally of a coarse conglomerate and grit, derived from the Paleozoic crystaline rocks, it degrades but little easier than the overlying rocks, and it generally forms abrupt escarpments.*

From the Burnet-Lampasas county line northward across Lampasas and Mills counties, the conglomerate increases very gradually in thickness, from thin bands to nearly one hundred feet. Grit and sand is often interstratified in it, and the pebbles become smaller and more siliceous. The surface outcrops of the sand all the while becomes greater northward. As the south line of Brown county is approached, sand and grit largely replace the conglomerate, the latter occurring at the basal portion of the bed. In the northern portion of Brown county the conglomerate element has nearly disappeared, being replaced by nearly two hundred feet of fine sand locally known as "packsand."

*All of the conglomerate which constitute the basal beds of the Cretaceous here is designated as Trinity, and forms a continuous bed, but is certainly not a contemporaneous deposit even across Burnet county. As was shown in the section, evidence was not wanting to show that the conglomerates in the northern part of the county were formed at a later period than was a portion of the Glen Rose (Alternating) limestones.

From Brown county to Red River the character of the sand is practically unvariable.

West of the main area Trinity sand occurs at the bases of and is parallel to the escarpments of the buttes and table lands located as follows:

Beginning in the southwest corner of Callahan county, west of Pecan bayou, a Cretaceous table land forms the water shed between the tributaries of the Brazos and Colorado rivers, across Taylor and Nolan counties, with an arm extending southeastward, from southwest Nolan county into Coke county, near Hayrick. Headwater erosion of the tributaries of Elm Fork of the Brazos river and of the Jim Ned creek, which belongs to the Colorado river drainage, has cut two gaps—the Buffalo and Cedar—in this water-shed table land south of Abilene. Another area of Cretaceous rocks extend from Mora and Table mountains, in Runnells county, southeast into Coleman county, where it divides, one arm passing south of Hord's creek to the Gulf, Colorado and Santa Fe Railway near Valera postoffice, and the other taking an easterly direction north of Hord's creek, ending in Robertson Peak.

Many of the creeks, with their branches, which have their source in this area, cut deep canyons and ravines that almost intersect the Cretaceous rocks. Long, irregular, promontory-like masses extend from the body of the table land out between the creeks, some of which end in isolated knobs or collections of buttes. Some of the typical of these remnantal buttes may be named in Horse mountains, at the mouth of the canyon of the Yellow Wolf creek, in Coke county; Long mountain and Hayrick mountain, with many other unnamed buttes, between the valleys of nameless creeks further east in Coke county; Church mountain stands out as a prominent landmark, three hundred feet high, on the "Red Beds" of the Permian at the end of a long projecting horn between Oak and Fish creeks; Bald Eagle mountain, south of Buffalo Gap, and the mountain between Buffalo and Cedar gaps are remnants from the erosion of Elm Fork of Brazos river and Jim Ned and Cedar creeks. Of the same character of buttes are Castle and East mountains at the mouth of Mulberry canyon, Moro and Table mountains in Runnels county, and the Tecumseh and Robinson's peaks in Callahan county west of Pecan bayou. Besides these, there are many others unnamed, of greater or less importance. Many of them have been cut completely adrift, and stand isolated from the parent mass on Permian or Carboniferous strata, while others are only partially separated, being connected with the larger body of Cretaceous rock by low necks of Trinity sand.

The Santa Anna mountain, in Coleman county, and the Double mountains, in Stonewall county, are examples of Cretaceous buttes, widely separated from the now shrunken parent area, yet still capped

by beds of Texana, Comanche Peak, and Caprina limestones. In these, as in many others, erosion has gone on until the level of the surrounding country is below the base of the Trinity, leaving the Cretaceous portion of the buttes resting upon truncated cones of Carboniferous or Permian rocks.

The Carboniferous-Permian contact passes beneath the Cretaceous area between Jim Ned creek and Pecan bayou, in a north to south direction, very near the east line of Taylor county. South of Jim Ned creek, it passes under the Trinity nearly one mile east of Content post-office, in Runnels county. East of this line the Trinity rests on Carboniferous strata, while to the west of it, Permian rocks underlie the Cretaceous.

Generally speaking, on the northwest sides of these Cretaceous table lands and hills the Trinity has less areal extent than on the south and southeast sides, because of the more precipitous character of the bluffs and escarpment faces. Whenever the sand occurs on the north side, except in occasional remnantal buttes, where the limestone has been removed by erosion, Caprotina, or Comanche Peak limestone caps the Trinity and forms precipitous bluffs. The width of the Trinity exposure along the northern and western borders is rarely more than one-fourth of a mile; in many cases less. On the southern and eastern borders, the face of the escarpment is not so precipitous, and the Trinity has greater width; sometimes, in the valleys of the streams, it is even two miles wide.

The cretaceous rocks here, as elsewhere in the Central region, dip toward the southeast, which is the cause of the abrupt escarpments on the north and northwest sides and of rolling slopes on the south and southeast sides of the plateau.

Extending in a northeasterly direction along the divide between the Elm Fork of the Brazos river and Hubbard creek from the Cretaceous highlands which follow the Permio-Cretaceous contact, is a stretch of rolling timber land "sand-roughs," which are considered to belong to the Trinity.

The whole length of the Trinity which belongs to these Cretaceous outliers is very nearly six hundred miles, with an average estimated width of one-half mile. By this low estimate there is an area of three hundred square miles of the sand.

The sand varies in thickness from nearly sixty to one hundred and sixty feet. On the west side of the valley of Bitter creek, in Nolan county, it is one hundred and twenty feet thick, with a band of conglomerate ten feet thick at the base. In Church mountain it is ninety feet thick; in Horse mountain nearly due south of Bitter creek, it is one hundred and sixty feet thick. About ten miles west of Horse mountain there is only fifty feet. Thus it will be seen that the sand of the Trinity varies in thickness in different localities. In fact this

difference in thickness is naturally to be expected, since a soft sand is laid down upon a hard, uneven surface.

TOPOGRAPHY OF THE SAND.—There are two topographic phases. The first is decidedly characteristic of both the Trinity and Paluxy sands, and as far as the vision is reliable, is almost an unfailing index to the rock, but it is dependent upon the associated beds overlying for its characteristics, while the second phase is independent of environments such as those governing the first for its features.

The first phase is represented in the escarpment faces and in the steep and westward facing declivities wherever the upper limit of the Trinity is exposed south of the Trinity river along the main border. As the valleys of the Colorado, Leon, Brazos and Trinity rivers enter the area of the sand, the escarpments turn their faces toward the rivers from the west, toward the southwest on the north sides of the valleys, and from the west to a northeasterly direction on the south sides of the same valleys; and only along these rivers can the Trinity sands be said to form valleys. They form the eastern slope of a generally wide valley, however, which extends along Red River, in Montague and Clay counties, southward across the valleys of the rivers to the Colorado. The upper portion of the Trinity sand, with the overlying beds of limestone, forms a bluff with sloping base along the eastern summit of this valley. From this summit extensive views can be had across the thick forests of the Cross Timbers. Although the Cross Timbers occupy this valley, yet the Trinity underlies only the eastern portion. From the base of this valley, which is nearly parallel to the Trinity-Paleozoic contact, a rolling country of wooded and prairie land begins rising gently toward the west. Near the eastern border timbered, bold topped buttes, limestone capped, rising from projecting spurs of the high land, ever stand as silent witnesses to the fact that they are remnants of beds that once extended over many thousand square miles of the "Denuded Area" toward the Staked Plains. Rapid denudation of the sand (more rapid than that of the overlying limestone) undermines the limestone and keeps an ever present escarpment, which is gradually moving eastward. There are two laws which govern the character of the topography here represented: The first is, that when a massive hard rock occurs in beds above a friable soft rock, bluff and slope topography is formed. The second is, that as a rule the hill side or mountain side opposite the direction of the dip of the rock is more precipitous than is the side in the direction of the dip. Both of these characteristics are present and admirably illustrated in the topography along the main border, and in the table lands and buttes on the Colorado-Brazos divide, in Callahan, Taylor, Runnels and Coleman counties, as already outlined for the occurrence of the Trinity sands.

The second phase of the Trinity topography has a representative in

the rolling "sand-roughs" found in northern Brown county, eastern Callahan and Eastland counties. A narrow belt of country similar in character extends northward between Elm Fork of Brazos river and Hubbard creek, in an irregular zone from the Cretaceous table land in the southeast corner of Taylor county. From these areas of sand the limestone that was once above them has been removed. Here the sand forms low oval hills, everywhere originally covered by a dense growth of dwarf oaks. The surface is generally level, very few of the hills being prominent. The term rolling is very applicable to this phase of topography. A friable sand of variable thickness deposited upon a hard floor of Paleozoic rocks, and subjected to the action of the prevailing atmospheric agencies, has given this character of topography.

GLEN ROSE (ALTERNATING) BED.

EXTENT.—On account of the peculiar topography of the Alternating series, an exact delineation of their areal extent is not possible without more detailed field work than their importance will at present warrant. Every river and creek having its source near the Trinity sand, at the western border, as well as the more important rivers that rise west of the Cretaceous area, such as the Colorado, Leon, Brazos and Trinity rivers, that enter the Alternating lime-marls, cut deep valleys down into and often through them. The rivers and some of the more important creeks flow across the alternating rocks and over higher beds to the southeast. The eastern limit of these beds intersects the Colorado river at Mount Bonnell, four miles west of Austin, and continuing northward crosses the principal river valleys as follows:

San Gabriel river, twelve miles above Georgetown, Williamson county; Lampasas river, about twelve miles below Youngsport; Leon river, near the mouth of Plum creek, in Coryell county; the Bosque river valley, on Houston and Texas Central Railway, four miles west of Walnut, Bosque county; and the Brazos river, at the mouth of Camp creek in the southwest corner of Johnson county. Near the contact, on the Leon river, timber appears upon the Paluxy sands between the Texana and the Alternating beds of the Fredericksburg and Bosque divisions respectively. It increases in importance and extent northward until it joins the timber belt of the Trinity sand in Wise county. The west edge of this timber belt, which is an arm of the Upper Cross Timbers, marks the eastern border of the Alternating series. The eastern limit of the main belt of the Upper Cross Timbers, which is the upper and eastern border of the Trinity sands, marks precisely the western parting of the Alternating beds, from the Colorado river northward through their whole extent.

Overlying the Alternating rocks on the divides between the principal of the valleys, beds of the Fredericksburg and Paluxy sand extend finger-like, from the main body of their respective beds in a northwest

direction, in some cases to the bluffs above the Trinity on the western border. Thus the valleys are occupied by Alternating limestone and marl and Trinity sand, surrounded wholly or in part by higher beds.

Very considerable portions of Travis, Burnet, Williamson, Lampasas, Coryell, Bosque, Hamilton, Erath, Somervell, and Hood counties are directly underlain by these rocks. Smaller areas, though of scarcely less importance, occur in Bell, Mills, Brown, Comanche, Parker and Wise counties.

THICKNESS AND GENERAL STRUCTURE.—From on their most southern extension, at Mount Bonnell, north of the Colorado river, the rocks of this bed continue to decrease in thickness along the line of exposure northward until they disappear between the Trinity and Paluxy sands, about the middle of Wise county. At this point the last representative of the limestone and marl series may be seen in a narrow band of fossiliferous calcareous argillaceous sandstone from six inches to one foot thick, in the midst of less calcareous and argillaceous sandstone. For fifty feet above the fossiliferous strata, the sand layers show various degrees of compactness. They are interstratified with bands of lignite and lignitic sand, and bear much silicified wood. Such exposures occur in a ravine near the Fort Worth and Denver Railway five miles northwest of Decatur.

The strike of the rocks at Austin northward passes one hundred miles southeast of Decatur, in Wise county. From this it may be observed that the line of exposure of the Alternating beds, as well as of the other beds of the Lower Cretaceous series, is not parallel to their strikes. Now, in going nearly due north 60 degrees west, perpendicular to the strike, from any point on the eastern border of the Alternating limestones, the rocks decrease more rapidly than they do in any other direction. The average decrease in thickness, going north along the eastern outcrop, is nearly three feet per mile. The average decrease toward the west is nearly five feet per mile. Along the Colorado section (Plate IX), which is almost perpendicular to the strike, the rocks decrease nearly ten feet per mile toward the northwest. At Mount Bonnell the depth of the Alternating series is estimated at seven hundred feet. On Sandy creek, twenty-eight miles north 50 degrees west of Mount Bonnell, they have a thickness of four hundred feet, making a decrease of nearly ten feet per mile. At Iredell, Bosque county, these rocks are four hundred feet thick, and at Mount Airy, Erath county, thirty-two miles north 78 degrees west of Iredell, they are fifty feet thick, which makes a decrease of ten feet and nine-tenths per mile, which direction is nearly opposite to the dip of the rocks. (Bosque section, Plate XI.)

Beneath Comanche Peak, Hood county, the Alternating limestone and marl is one hundred and fifty feet thick, and at Twin Mountain, thirty-six miles due west of Comanche Peak, the same bed is only five feet thick, giving a decrease of four and two-tenths feet per mile.

The importance of a thorough understanding of the rate of decrease in thickness of these beds from south to north, and of their structure, becomes apparent when the economics of artesian water are to be considered.

TOPOGRAPHY.—Under a general consideration there is one phase of topography of the Glen Rose (Alternating) bed, but when environments, such as the effect of associated rocks, are brought to account there may be three phases. Two of these occur south of the southern limit of the Paluxy sand, while the third belongs to the tongue-like extension between the Trinity and Paluxy sand beds north of the Leon river.

To one who is versed in geology and topography, and who has observed how certain topographic phases invariably follow the same geologic conditions, it is only necessary here to explain the geology, and the topographic picture will be clearly seen. When it has been stated that there are horizontal layers of comparatively soft limestones and still softer marly bands of varying thicknesses, from a mere band to from six to eight feet, following each other in quick succession and forming an elevated prairie land, a topographic picture of rolling hills and deep valleys, with parallel benches and terraces, which are governed in height by the thickness of lime and marl beds, and which extend around the hills and valley slopes, is brought to view about as vividly as if one stood upon the field and the landscape lay before him. This bench and terrace topography is the leading phase of these beds.

The two characters of this phase may be said to be accidental, because when affected alone by atmospheric agencies the one phase prevails. South of the Leon river the heavy beds of the Fredericksburg check the rapid erosion of the Alternating limestones and cause them to form very precipitous slopes and almost to lose the bench and terrace phase. When these superimposed heavy beds approach very near a valley of rapid erosion, as for instance when a creek or river in its winding course cuts rapidly against its banks, the same thing is repeated at the base of the valley instead of the summit. When both these conditions are present this character is doubly pronounced, and it seems as if another character of rock had entered into the beds.

This character of topography occurs in its greatest beauty along the valley of the Colorado river from Mount Bonnell to the western border of Travis county, also along the San Gabriel and Lampasas rivers. It prevails to some extent in the valleys of some the smaller streams. Where a hillside is comparatively steep and smooth with precipitous bluffs, it must not be thought that a new character of rock has appeared. Instead of a change of rock there is to be considered a phase of topography. Mount Bonnell is a typical illustration of this. The Colorado river has lately so encroached on its western side that very steep, and

in places impassable bluffs have been formed, obliterating the characteristic topographic phase of these beds. It is only necessary to follow the beds from the precipitous western face of this mountain around to its east side, or northward along the western slope of Mount Barker, to observe them change from the bluff to the bench and terrace character. It is north of the Colorado basin, toward the sources of the San Gabriel and the tributaries of the Lampasas river, that the second phase of the topography of the typical Alternating beds occurs. Here the beds of the Fredericksburg have, in the main, been removed, and the Alternating rocks are alone left to be eroded and worn in their peculiar form. It is here that the hills are sharply cut with an occasional conical knob, and with bench and terrace structured sides.

Northward of the Leon river, where the Alternating limestones are inclosed between the Trinity and Paluxy sands, the same topography continues, but here it is not so characteristic outside of the rapid erosion-valleys of the rivers. Here the rocks above, viz: the Paluxy and Trinity sands have the same structure, and the Alternating rocks remain as a generally inclined plane between them.

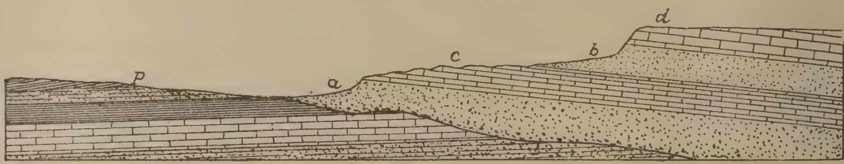


Figure 9.

Topographic phases of Trinity, Glen Rose and Paluxy rocks north of Leon river. P. Paleozoic. a. Trinity phase. b. Paluxy phase. c. Glen Rose phase. d. Comanche Peak phase.

PALUXY SAND BED.

To delineate this bed is necessarily a recapitulation, at least in part, since full details of many localities on it have been given. However, a general view of the bed with reference to its extent and importance will be of value.

Position.—Its position is at the top of the Bosque series, directly underlying throughout its extent the Texana bed. Between the Leon river and a point five miles northwest of Decatur it rests upon and grades gradually into the lime-marl of the Alternating bed,

From the above named point to Red River it joins the Trinity sand without a perceptible division line. North of the Alternating bed extension, at every point of its occurrence, it separates the Trinty bed from the Texana bed, the basal bed of the Fredericksburg division. The Paluxy sand is considered to be represented in the upper half of the Cretaceous and beneath the Fredericksburg west of the main Cretaceous border.

EXTENT.—On the north side of the Colorado river valley, near the source of Hickory creek (Hickory Creek Section), a narrow belt of sand occurs just beneath the Texana bed; but, as this narrow bed extends toward the east, it soon changes into an arenaceous limestone. This same sandy bed is present in the same corresponding position beneath the Texana bed in Bachelor's Peak near the northeast corner of Burnet county. Here, too, it becomes more calcareous toward the east, and finally blends into an arenaceous limestone. Beneath Bachelor's Peak it is a calcareous and argillaceous sandstone fifteen feet thick. The Paluxy bed cannot be positively distinguished from the Alternating rock until the valley of the Leon river is reached. Here, near the eastern limit of Comanche county, the sand is nearly fifty feet thick; but on passing down the valley to its most easterly exposures near Jonesboro, Coryell county, it thins out to a narrower band, fifteen feet thick.* At Dublin, and along the Bosque river valley toward Walnut, Bosque county, it is fifty feet thick. Beneath Comanche Peak it is one hundred feet thick. At Weatherford, Parker county, there is one hundred and twenty feet of sand, and near Decatur, Wise county, it has reached a grand development of one hundred and eighty feet. Northward, beyond this point, its lower limit could not be located, but there is no doubt that the development continues northward along the western border toward the pre-Cretaceous interior.

GENERAL CHARACTERS.—As a whole, the Paluxy bed is a body of homogeneous, fine-grained, porous, compact, but not indurated sand, bearing an abundant fossil flora in the form of silicified and lignitized wood. In detail it is false-bedded on an extensive scale, and often finely and beautifully laminated. Lenticular bands of impure clay occur with lignitic sand in like form. The basal position of the sand becomes calcareous, and dimension flags of compact shell-limestone occur in the marly sand. Near its upper limit the sand becomes argillaceous in some localities and occasionally there are quite pure clays.

TOPOGRAPHY.—With few exceptions there is only one phase of topography represented upon the Paluxy sand. Except on an occasional highland, such as occurs north of the Paluxy creek valley, in Hood county, where higher beds have been eroded, Fredericksburg limestones occur above the friable sand.

Thus we have the topography peculiar to beds of friable sand protected by compact limestone above steep slopes, upon the upper portion, and a gradual decline in the grade toward the base of the sand. The hard limestones tend to retard the eastward tendency to erosion, and the consequence is that the erosion of the sand is greater beneath the bluffs and steep slopes of the Texana, Comanche Peak, and Caprina beds than it is near the lower limit.

* R. T. Hill in Bulletin of the Geological Society of America, Vol. No. 2, page 510.

As soon as the ground in this upper sand portion becomes bare of turf and timber growth, the ever loose soil and sand is cut into gullies and rapidly removed to the lower gently-rolling portion, where the currents are checked or lost in the sand and a part at least of the sand is allowed to remain for a period. This phase of topography is characteristic of the Paluxy sand from the Leon river, in Hamilton county, along the escarpment of the Upper Cross Timbers, through Dublin, Erath county; thence down the Bosque river valley to a point nearly south of Walnut; thence in a tortuous line, through Erath county, around the Bosque and Brazos river divide, to the Brazos river at the southwest corner of Johnson county; from this point northward, through Acton, Parker county; Weatherford, Veal's Station, and Dido, Parker county, on the Trinity river; thence through Decatur, Wise county; Forestburgh, St. Joe, Montague county, to Red River north of Bulcher, Cooke county. The same character of topography characterizes the Paluxy sand around every Cretaceous outlier between the Upper Cross Timbers and the Staked Plains.

Where overlying rocks have been removed from a considerable area, the surface is rolling and covered with timber.

DETAILED SECTION OF THE BOSQUE DIVISION.

These sections are intended to show, briefly, the structural, physical and dynamical features of the rocks, as well as the relations of the Trinity, Glen Rose (Alternating) and Paluxy beds to each other, as shown principally from a stratigraphic point of view.

The graphic representations, given in a series of linear sections, show generally the contact, dip, thickness and faulting of the beds to scale, together with detailed columnar sections, also drawn to scale, each opposite its point on the profile. The relative adjustment of the columnar sections is arbitrary, and no reference is had to their differences in elevation.

Much aid was obtained in the field from the topographic sheets of the United States Geological Survey and from railway elevations. Vertical and horizontal measurements were made with barometer and pedometer, checked by the United States sheets; and compass and clinometer were employed to ascertain dips and strikes of the rocks. Outside of the area occupied by the United States topographic sheets, the railway profiles were employed as a basis of horizontal and vertical measurements, and these profiles were supplemented by the pedometer and barometer. At the point of each columnar section the rocks were studied closely, in detail, from the lowest to the highest elevation.

THE COLORADO SECTION.

Beginning at the junction of Hamilton and Hairston creeks, in Burnet county, the section was extended south 50 degrees east, passing the asylum for the insane, in North Austin, and ending near the Colorado river, southeast of the city.

A short distance below the mouth of Hairston creek Hamilton creek passes over the edge of Silurian limestones, to soft Carboniferous shales. At this point the Colorado section begins. Here heavy Silurian limestones dip 70 degrees south 60 degrees east. The Carboniferous shales, with occasional bands of flaggy Carboniferous sandstones resting on these Silurian rocks, continues beneath the Cretaceous conglomerate of the Trinity bed.

SECTION NO. 1.

Hickory creek section begins with the Colorado river level, at the mouth of Hickory creek and continues to the top of the divide between Hickory and Cow creeks.

1. Laminated flaggy sandstones and friable light blue clay of the Carboniferous (Coal Measures) formation, from the Colorado river level upward to the base of the Trinity conglomerate, the laminated sandstones containing prints of ferns, nearly . . . . . . 100 feet.

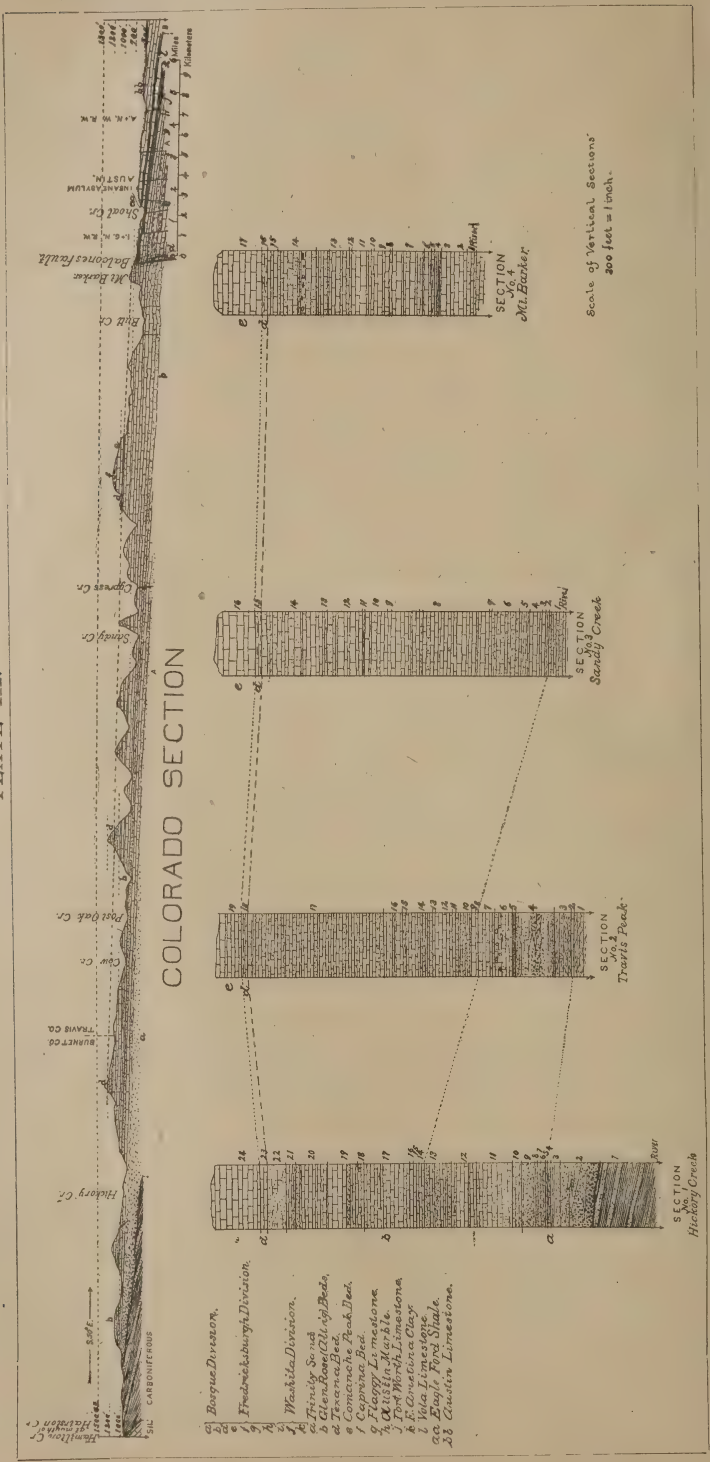
Trinity Bed.

2. Basal Trinity conglomerate of pebbles of limestone, quartz, chert, granite and schist, well rounded in a cement of ferruginous yellow and red gritty sand . . . . 50 feet

Some of the pebbles at the base are from four to six inches in diameter. They decrease in size, however, upward from the base, until we obtain a false-bedded calcareous shell grit at the top.

3. Bands of friable bluish shale and calcareous sand, stratified. Fragments of oyster shells are common in the calcareous sandstone . 15 feet.
4. Brecciated grit, composed of worn fragments of oyster shells and shells of other mollusca, with sand and fine pebbles, stratified in false beds . . . . 5 feet.
5. Ostrea beds, magnesian lime cement, fossils *en masse* . . . . 3 feet.
6. Cross-bedded shell breccia, containing many small rounded grains and pebbles of quartz, flint and granite sand. Fossils: *Trigonia* and small bivalves, and an *Ammonite* . . . . 7 feet.
7. Friable yellow sand . . . . 5 feet.
8. Red sand, unconsolidated . . . . 3 feet.
9. Conglomerate similar in character to No. 2, with the exception that the pebbles are smaller and more worn, grading into sand below and into calcareous sand above . . . . 25 feet.
10. Yellow calcareous sand, stratified . . . . 15 feet.
11. Calcareous sand at base, grading upward to a siliceous limestone at the top, barren of fossils . . . . 55 feet.
12. Marly magnesian limestone . . . . 40 feet.
13. Bands of conglomeritic and calcareous sandstone, alternating with beds of arenaceous limestone, the arenaceous limestone predominating . . . . 40 feet.

PLATE IX.


COLORADO SECTION
SECTION No. 1 Hickory Creek
SECTION No. 2 Travis Peak
SECTION No. 3 Sandy Creek
SECTION No. 4 Mt. Barker
Scale of Vertical Sections 200 feet = 1 inch.
Bosque Division.
Fredericksburgh Division.
Washita Division.
a Trinity Sand
d Texana Bed.
e Comanche Peak Bed.
f Caprina Bed.
g Flaggy Limestone.
j Fort Worth Limestone.
aa Eagle Ford Shale.
Austin Limestone.
CARBONIFEROUS
Hickory Cr.
Cow Cr.
Post Oak Cr.
Sandy Cr.
Cypress Cr.
Bull Cr.
Mt. Barker
Balcones fault
Shoal Cr.
AUSTIN.
INSANE ASYLUM
TRAVIS CO.
BURNET CO.

The sandstone contains grains of silica, from the size of a pea to the most minute particle, and small subangular fragments of clay in the cement of lime.

Glen Rose (Alternating) Bed.

14. Limestone, with *Monopleura* . . . . 3 feet.
15. Magnesian limestone, with bivalves, gasteropods and *Goniolina* . . 5 feet.
16. Limestone, containing abundant *Caprotina* (*Requienia*) *penguiscula*. 7 feet.
17. Barren arenaceous limestone, in beds varying in thickness and hardness . . . . 70 feet.
18. Thin bands of limestone, with *Exogyra* . . . . 10 feet.
19. Barren yellow limestone, twenty feet; narrow ledge of brecciatic limestone, five feet; heavy magnesian limestone, with magnesian sulphide formed on protected surfaces, twenty feet . . . . 45 feet.
20. Thin bedded, yellowish limestone, slightly arenaceous, ending in a thin band of calcareous sand . . . . 50 feet.
21. Thin bands of argillaceous, marly limestone . . . . 15 feet.
22. Calcareous sandstone, in thin strata, without fossils . . . . 30 feet.

Fredericksburg.

23. *Exogyra texana* bed, chalky crumbling limestone, with *Gryphæa pitcheri*, *Exogyra texana*, *Toxaster texana*, *Holectypus platanus*, *Goniolina* and *Cardium hillanum* . . . . 10 feet.
24. Comanche Peak bed, chalky massive limestone . . . . 70 feet.

Twenty feet of the limestone at the top of this section is massive and nearly pure.

SECTION NO. 2.

The Travis Peak section was made, beginning at the junction of Post Oak and Cow creeks, below Travis Peak postoffice, and ending at the top of Travis Peak.

Trinity Bed.

1. False-bedded gritty shell limestone, beginning at the *Ostrea franklini* bed and continuing downward to the lower conglomerate of No. 2 of the Hickory creek section . . . .
2. *Ostrea franklini* bed, masses of *O. franklini* in magnesian lime cement . . . . 5 feet.

Where this bed is protected from rapid erosive agencies, salts of magnesia attack and disintegrate the fossils.

3. Finely comminuted shell breccia limestone, false-bedded . . . . . 25 feet.

Quantities of siliceous sand and grit occur in the shell breccia, the particles of which increase in size and number from the base upward to the conglomerate. The Trigonia and associated fossils (except the Ammonites which are rare) given in the same bed, No. 6, of Hickory creek section, occur on Cow creek in great abundance.

4. Purple and red calcareous and argillaceous fine compact sand, at base ten to fifteen feet thick, varying in character, color and thickness of strata, succeeded by varying beds of friable sands and grits, clear, or iron stained. These sands, toward the center of the bed, blend with a conglomerate, which in turn grades into compact calcareous sand at the top; total thickness of bed . . . . 60 feet.

Glen Rose (Alternating) Bed.

5. Blue clay and argillaceous sand . . . . 5 feet.
6. Heavy beds of calcareous magnesian sand with nodules and geodes of dog-tooth spar . . . . 25 feet.

Under overhanging cliffs and ledges of rock where the surface is protected from the weather, flocculent powder of magnesia sulphate is formed.

7. Magnesian argillaceous sandy limestone . . . . 25 feet.
8. Limestone, in thin beds with *Monopleura* . . . . 3 feet.
9. Thinly bedded limestone, with *Caprotina* (*Requienia*) . . . . 7 feet.
10. Calcareous shaly sandstone . . . . 25 feet.
11. Stratified magnesian calcareous sand . . . . 8 feet.
12. Limestone . . . . 22 feet.
13. Thin bands of marly limestone, small *Exogyra* sp ind. and *Goniolina* . . . . 5 feet.
14. Arenaceous marly limestone, fifteen feet. More compact limestone, in thinner and more persistent beds, twenty-three feet . . . . 38 feet.
15. Limestone, with *Ostrea* . . . . 2 feet.
16. Arenaceous and argillaceous marls and limestones, alternating in thin beds . . . . 30 feet.
17. Marly, slightly argillaceous, limestone, thirty to fifty feet thick, alternating with thinner bands of harder and more arenaceous limestone. The harder bands project from the hillsides and form benches . . . . 200 feet.

Magnesian limestones occur in this bed, but distinct lines could not be drawn, as one grade of limestone blends into another.

Fredericksburg.

18. *Gryphæa pitcheri* and *Exogyra texana* in marly crumbling limestone or lime marl . . . . 10 feet.
19. Comanche Peak chalky limestone to the cap rock of Travis Peak . . 20 feet.

SECTION NO. 3.

The Sandy creek section begins at the Colorado river level at the mouth of Sandy creek, and continues to the top of the butte one mile from the river.

1. Very fine-grained calcareous sand, laminated and stratified, easily splitting into flagstones along the lamination lines . . 30 feet.
2. Friable calcareous shale, rapidly disintegrating, and forming cavities beneath hard limestone . . . . 4 feet.
3. Massive blue limestone, containing *Rudistes*, *Monopleura*, etc . 4 feet.

This is the same bed as No. 14 of Section No. 1, and No. 8 of Section No. 2.

4. Limestone, even-bedded . . . . 22 feet.
5. Soft calcareous clay, containing numerous *Goniolina*, *Arca*, small bivalves, and gasteropods . . . . 20 feet.
6. Massive yellow semi-crystaline arenaceous limestone . . . . 40 feet.
7. Calcareous clay, bearing numerous foraminifera, *Goniolina* and *Arca* (?) . . . . 5 feet.

THE CRETACEOUS AREA NORTH OF THE COLORADO RIVER
GEOLOGICAL MAP
showing Divisions and Distribution over a typical area
BY
J. A. TAFF AND S. LEVERETT
Topography principally from the Topographic Sheets of the United States Geological Survey
SCALE
0 1 2 3 4 5 6 7 8 9 10 Miles
0 1 2 3 4 5 6 7 8 9 10 Kilometers

8. Porous granular limestone, earthy yellow colored, variable in thickness of layer and in persistence in weathering . . . . 150 feet.
9. Thin-bedded limestone, with fragments of *Ostrea subquadrata*. 1 foot.
10. Limestones, similar in character to No. 8, in variable shades of yellow on fresh fracture. It shows varying degrees of resistance to weathering . . . . 40 feet.
11. Thin sheets of limestone, with *Monopleura* . . . . 2 to 3 feet.
12. Alternating bands of limestone, similar to that of No. 10 . . . 60 feet.
13. Thin-banded limestones, with gasteropods, echinoids, *Trigonia* and small *Exogyra* . . . . 2 feet.
14. Alternating beds of impure arenaceous and marly limestone, similar to Nos. 10 and 12 . . . . 100 feet.

Fredericksburg.

15. Crumbling marly limestone, bearing *Gryphæa pitcheri* and *Exogyra texana*, with associated echinoids and foraminifera . . . . 10 to 15 feet.
16. Comanche Peak chalky limestone, with massive beds twenty feet thick at the upper edge . . . . 60 feet.

SECTION NO. 4.

Beginning at the mouth of Bull creek, the Mount Barker section continues to the top of Mount Barker, at the mouth of Colorado river canyon, four miles west of Austin.

1. Granular arenaceous light gray limestone and calcareous sandstone, in thick beds, from the river level upward . . . . 18 feet.
2. Massive white limestone, filled with *Orbitolina texana*, (Roemer) . . 20 feet.
3. Slightly arenaceous, marly, white compact limestone . . . . 20 feet.
4. Argillaceous, friable and hard limestone, containing nodules of anhydrite . . . . 10 feet.

The lower portion is soft, but the upper portion is hard subcrystaline limestone.

5. Shaly, thin-banded, arenaceous limestone, with *Monopleura* . . . . 1 foot.
6. Impure light brown limestone, in thick beds . . . . 10 feet.
7. Compact light yellow, massive, or thick-bedded limestone . . . . . 50 feet.
8. Goniolina bed; soft marly limestone, with many specimens of Goniolina (?) . . . . 2 feet.
9. Thin and thick layers of yellow and dark mottled and light yellow limestone, composed largely of minute shell fragments . . . . . 25 feet.
10. Mass of small bivalve fossils in yellow arenaceous limestone . . . . 2 feet.
11. Compact fine-grained limestone, in ledges, varying in degrees of hardness . . . . 50 feet.
12. Fossiliferous yellow limestone, composed of small bivalves in mass of shell fragments and lime . . . . 3 feet.
13. Alternating, slightly arenaceous, hard, granular shell limestone, light blue to yellow in color, some of the bands having an oolitic appearance . . . . 50 feet.
14. Yellow, porous, arenaceous limestone and siliceous limestone, in ledges, varying in thickness from two and three feet to two and three inches . . . . 75 feet.

Geodes and nodular masses of Celestite occur abundantly in the lower portion of this bed. The Celestite beds of Mount Bonnell belong to this rock.

15.	Fossiliferous, semi-crystaline, compact and fine grained limestone, in yellow and white bands	15 feet.
16.	Marly friable limestone, with abundant *Gryphæa pitcheri* and *Exogyra texana* with echinoids and *Goniolina*	10 feet.
17.	Chalky Comanche Peak limestone, with massive beds at the top . .	75 feet.

At the mouth of Comb's Hollow, about four miles southeast of Travis Peak postoffice, the *Ostrea franklini* horizon, No. 5 and No. 2 of Sections No. 1 and No. 2, approach the low water line of the river. Here the conglomerate of No. 9 and No. 4, of Sections No. 1 and No. 2, is represented by a thick bed of grit and calcareous sand. The vertical section of the Alternating bed here, as well as that of others on Camp creek northwest of Smithwick Mills, and on Cypress creek below Anderson's Mill, are repetitions of the section given above, with exception of slight variations in lithologic features.

From these observations the facts are conclusive:

1. That the *Gryphæa* bed and the overlying Fredericksburg beds, throughout their exposures in this section, are persistent in every particular and do not vary in thickness.

2. That the calcareous sand with other arenaceous strata beneath the Texana bed in vertical section No. 1 changes to arenaceous and purer limestone, and increases in thickness of strata toward the southeast.

3. That the strata of the Trinity bed blend and shade into the overlying rocks of the Glen Rose bed so imperceptibly that the line of demarkation between them is not discernible, and that the material composing the conglomerate and grit, No. 9 and No. 4 of Sections No. 1 and No. 2, decrease in size, and grade into grit and calcareous sand, until the conglomerate disappears beneath the level of the river, near Sandy creek, toward the southeast.

4. And that the Glen Rose bed, as a whole, is here lenticular in form, and that if these beds were restored toward the west for a distance of fifty miles, the Trinity would approach the Texana bed.

BOSQUE SECTION.

The section from which the division takes its name, and which comprises the three beds in typical development, was begun at the base of the Trinity sands, ten miles west of Dublin, Erath county, and continued eastward along the Houston and Texas Central Railroad to the top of Comanche Peak bed, near Walnut, Bosque county.

The profile of the section is the level of the railway, which practically marks the line of lowest exposure of the rocks. From Alexander to Walnut the section line is in the valley of the Bosque river, and the rocks from the center to the sides of this valley were studied together with those of its medial portion.

Between the Leon river, the western limit of the section, and Walker's branch, the Carboniferous rocks are exposed. They consist of a series of pale blue clays, sandy clays and bands of finely laminated sandstone. The clays are friable and erode easily, while the sandstone beneath is heavy and indurated. In immediate contact with the base of the Trinity sands there are reddish, gritty sands, and fine red, shaly sand, nearly horizontally bedded. The shaly sand contains light blue splotches. A marked resemblance between this sand and some of the red sand beds of the Permian near Buffalo Gap, in Taylor county, is noticeable. Resting unconformably on these beds, the Trinity sands begin with a coarse conglomerate of pebbles and sand. The prevailing pebbles are white and pink quartz, brown and red quartzite, black and white jasper, subangular in shape; and there are occasionally large worn pebbles of conglomerate, composed in part of pebbles similar to those in the bed. Great quantities of silicified wood, in the form of fragments of trunks and branches of trees, occur near the base of this Trinity conglomerate, some of them being of several hundred pounds weight. This conglomerate continues upward for nearly twenty feet, the pebbles growing less and less in size, until the conglomerate becomes a fine yellow "pack-sand."

The outcrops and widths of the exposures of the different beds from the Carboniferous to the Texana beds may readily be observed by reference to the section.

The three beds which form the Bosque division are typical in their forms and exposures along the line of this section, and on each side of the valley of the Bosque river. The selected vertical sections well illustrate, in detail, their occurrence and relations.

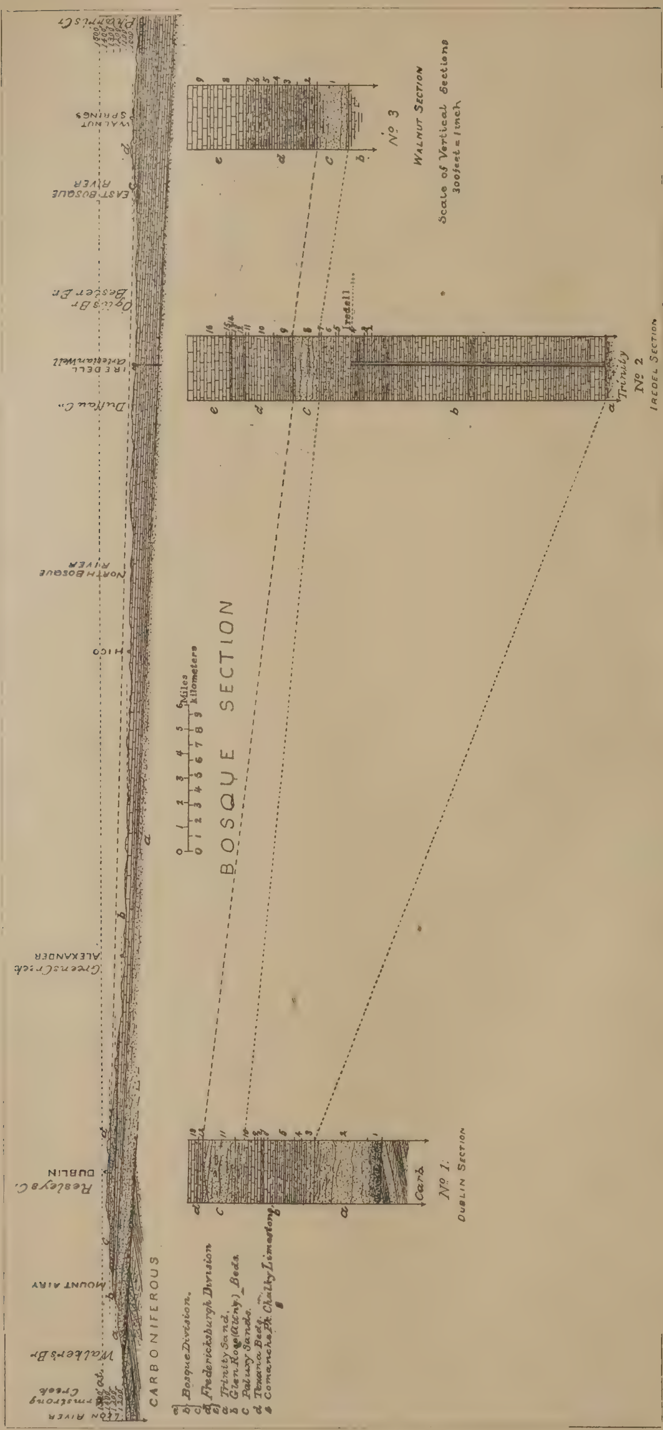
SECTION NO. 1.

The Dublin section includes the rocks of the Bosque division from the base of the Trinity bed upward to the Texana bed at their western extension near Dublin.

Trinity Bed.

1. Conglomerate of pebbles and sand, which decrease in size from small bowlders at the bottom to fine grains of sand at the top. 20 feet.

PLATE XI.


BOSQUE SECTION
Miles
kilometers
CARBONIFEROUS
No. 1.
DUBLIN SECTION
No. 2
IREDEL SECTION
No. 3
WALNUT SECTION
Scale of Vertical Sections
300 feet = 1 inch
DUBLIN
MOUNT AIRY
ALEXANDER
HICO
NORTH BOSQUE RIVER
IREDELL
EAST BOSQUE RIVER
WALNUT SPRINGS
LEON RIVER
Trinity
Iredell

Silicified wood occurs abundantly near the base, with scattering fragments still higher up in the beds. The large pebbles in masses are found near the base only, while above this a fine, yellow, siliceous sand forms the body of the rock.

2. Compact, fine, friable sand, often false-bedded, with thin bands and lenses of impure clay . . . . 80 feet.

Thin layers of lignitic material occasionally occur in the clay, and also fragments of lignitized wood. Fragments of silicified wood rarely occur in the sand.

3. Very calcareous, fucoidal sandstone, in ledges, partially indurated . . . . 20 feet.

In this horizon of the sand, and especially in the upper portion of it, there are nodules of iron sandstone, some of which have cavities at their centers filled with fine loose sand. This ore is of no commercial value.

The Trinity sand proper is a fine quartz sand, clear white to pale red in color. In the clearest sand, however, there are minute grains of colored material. The sand is almost invariably false-bedded. In places the beds are several feet in thickness, and when seen in a small exposure they might be considered as massive. At other places the sand is minutely false-laminated with thin wedges of lens-shaped masses of sandy clay or nearly pure clay, generally light blue in color. Associated with this impure clay are occasional patches and thin bands of lignite and lignitic clay. No fossils except the silicified wood and lignite were found in the sand proper.

Glen Rose Bed.

4. Limestone of finely comminuted shells, with a thin band of lime marl at the upper edge . . . . 10 feet.

Ostrea camelinis occurs at the contact of No. 3 and No. 4.

5. Alternating marly lime and hard limestone . . . . 40 feet.

The marly lime predominates. It occurs in beds from five to fifteen feet, while the hard limestone is from one foot to five feet in thickness. Numerous specimens of *Arca*, *Trigonia crenulata* (?) and gasteropods occur near the lower portion of this bed, also *Exogyra* sp. ind. and a small oyster. Most of the limestone ledges contain small fragments of oysters and other shells, and are hardened into semi-crystaline limestone. These hard ledges project from the hillside and form benches, while the marly and more readily disintegrated lime is being removed by erosion.

6. Hard limestone . . . . 5 feet.

A thin band of *Exogyra* sp. ind. and oyster shells occurs in contact with this limestone.

7. Marly limestone . . . . 6 feet.
8. Hard shell limestone . . . . 5 feet.
9. Band of small *Exogyra* and *Ostrea* in mass . . . . 6 inches.
10. Lime marl at base, grading upward into sandy marl at the top . 30 feet.

This is the transition horizon from the Alternating series to the Paluxy sands.

Paluxy Sand.

11. Cross-laminated, false-bedded, fine-grained sand, with occasional thin lenticular seams of clay . . . . 50 feet.

This sand is white, yellow and pink, and in every respect resembles that of No. 2. It is false-stratified and laminated, containing lenticular bands and lenses of clay. The component particles of sand of each are so closely identical that they point to the same origin. Beautiful exposures of this sand were seen in the banks of the creeks to the east and west of the Fort Worth and Rio Grande Railway three miles south of Dublin.

Texana Bed.

12. Marly lime, grading upward sharply into limestone of the Texana bed . . . . 5 to 10 feet.
13. Texana bed, full thickness not exposed. *Gryphæa pitcheri*, *Exogyra texana*, *Trigonia crenulata* occur abundantly . . . .

Eastward from Dublin a descent is made from the *Exogyra* bed to the Paluxy sand, and from this sand, in turn, to the Alternating series in the valley of Green's creek. The erosion of Green's creek has carried the sand away and cut into the Alternating rocks nearly one hundred and fifty feet.

SECTION NO. 2.

The Iredell section comprises the beds from the Trinity sand below Iredell to the Caprina limestone capping Johnston's Peak, three miles south of Iredell.

Glen Rose Bed.

1. Alternating limestones, from the Trinity bed to the level of the Bosque river at Iredell . . . . 360 feet.

An artesian well, three hundred and seventy-five feet deep, penetrated the limestone beneath the town. The base of the well touches the Trinity sand, from which an abundant supply of water is obtained.

2. Blue calcareous shale, at the bed of the river, one-fourth mile above Iredell, exposed . . . . 2 feet.

Fragments of lignite and particles of iron pyrites occur in this shale.

3. Small *Ostrea* and *Exogyra*, in mass . . . . 6 in. to 1 foot.
4. Alternating bands of thick marly lime and thin hard ledges of semi-crystalline shell limestone . . . . 40 feet.

Arca and small Ammonites allied to *A. pedernales* (Roemer), and *Nerinea* occur abundantly in the marly lime. Fragments of oysters and other shells compose the mass of the hard strata.

5. Limestone, *Exogyra* very numerous . . . . 5 feet.
6. Marly sand, gradating upward into calcareous indurated and friable sand and impure clay . . . . 20 feet.

The sand and impure clays are interstratified.

7. Hard crystalline shell limestone . . . . 1 to 2 feet.

Paluxy Bed.

8. Paluxy sand . . . . 40 feet.

The structure of this sand is practically the same as of that in the Dublin section. At the upper edge, and extending down nearly thirty feet, there are considerable quantities of nodular ferruginous sandstone: Many nodules have cavities at the center filled with loose fine sand, in the same manner as the nodules occurring beneath the alternating group west of Dublin. See No. 3, Dublin section.

Texana Bed.

9. Marly limestone with abundant *Gryphæa pitcheri*, *Exogyra texana*, *Trigonia*, *Natica*, &c. . . . . 30 feet.

The *Gryphæa* form massive rocks at the upper part of the horizon.

10. Chalky argillaceous limestone, with a few *Gryphæa pitcheri* . . 30 to 40 feet.
11. Second *Gryphæa pitcheri* horizon. Fossils in mass and small . 1 to 3 feet.
12. Chalky limestone . . . . 15 feet.

This limestone weathers into small sub-angular balls and yellow marl.

13. Third *Gryphæa pitcheri* horizon. The fossils are small and in mass cemented by lime . . . . 2 to 3 feet.
14. Argillaceous, soft, bituminous lime marl, cream colored to blue . 5 feet.
15. Chalky limestone, with large *Exogyra texana*, *Toxaster texanus*, *Holectypus planatus* and *Natica* . . . . 5 to 6 feet.
16. Comanche Peak bed; compact chalky limestone . . . . 60 feet.

Ten feet of indurated chalky limestone forms the cap rock of Johnston's Peak.

No. 10 of this section is the horizon designated as Walnut clays by R. T. Hill.* As the marly lime disintegrates, a yellow plastic marl is formed. As to the *Exogyra texana*, it occurs through the Texana beds from the Paluxy sand to the Comanche Peak chalky limestone, which may be seen two miles west of Dublin, at Johnston's Peak, two miles west of Walnut, where the *Exogyra texana* comes in contact with the sand, and at numerous other localities.

The Texana bed, as a whole, is a lime marl, fossiliferous from bottom to top, varying from a soft marl to a hard rock.

SECTION NO. 3.

The Walnut section was constructed in ascending order from the base of the Paluxy to the Caprina bed.

* Bulletin of the Geological Society of America, Vol. II, p. 512.

Paluxy Bed.

1. Paluxy sand—fine laminated and stratified, white to yellow "pack-sand" . . . . 50 feet.

Large segregations of indurated sand having a quartzitic texture, occur in the upper portion of this bed.

Texana Bed.

2. Thick marly lime and thin compact limestone alternating . . . 30 feet.

In the compact strata the *Gryphæa pitcheri* fossils form the mass of the rock. In the upper layers of like character, which occur in the banks of the branch on the west side of Walnut, there is scarcely sufficient lime matrix to cement the fossils. The marly lime strata contain *Gryphæa* and *Exogyra* in less numbers, but they contain many Ammonites, *Arcopagia texana*, *Cardium hillanum*, *Natica*, and *Trigonia crenulata*. *Exogyra texana* occurs in abundance at the base.

3. Marly limestone, probably argillaceous . . . . 30 feet.

On first exposure it appears to be a whitish yellow chalky limestone.

4. Second *Gryphæa* horizon—compact limestone in thin layers with numerous small *Gryphæa pitcheri* . . . . 1 to 3 feet.
5. Marly lime, same as No. 3 . . . . 25 feet.
6. Third *Gryphæa* horizon, same in character of rock and fauna as No. 4 . . . . 1 foot to 6 in.
7. Chalky limestone, becoming more massive upward. It contains large *Exogyra texana*, *Toxaster texanus*, *Holectypus planatus*, *Cardium hillanum* and *Arcopagia* . . . . 10 to 15 feet.

Comanche Peak Bed.

8. Comanche Peak chalky limestone . . . . 60 feet.

The line between No. 7 and No. 8 cannot be clearly defined, since one grades into the other lithologically.

Caprina Bed.

9. Caprina chalky limestone caps the mountain south of Walnut . 30 feet.

Caprina crassifibra (Roemer) and *Caprotina* sp. ind. occur in this limestone.

It is a valuable fact that the changing condition of the upper Alternating beds toward the Paleozoic area, as indicated in the Colorado section, is clearly and beautifully illustrated in the Bosque section. In the Hickory Creek section, No. 1 of the Colorado section, a bed of sandstone is foreshadowed in horizon No. 22, which is a calcareous sandstone, and which decreases in percentage of siliceous material toward the southeast in vertical sections Nos. 2, 3 and 4. In the Bosque section this culminating Alternating horizon has a full representative in the Paluxy sand bed, into which the same Alternating beds grade through a horizon of siliceous lime marl. The Paluxy sand is a marked feature of the Bosque section, and has sufficient prominence to be characterized as a bed.

Another fact is worthy of notice, viz: that the *Ostrea camelinis* (MS. of Cragin), occurring in the middle of what was considered the Trinity conglomerate of the Colorado section, No. 2 of Travis Peak section, is found in the Bosque section near Mount Airy at the base of the Glen Rose (Alternating) bed. It may be observed too, that the Texana bed, which is ten to fifteen feet thick on the Colorado river, has increased in thickness to one hundred feet in the Bosque section.

The Glen Rose bed as a whole presents the same phases here as it does in the Colorado section, but it shows a more decided character in the changing conditions of the beds from marl at the base to hard limestone, and in the passing from the limestone through a series of marly and shell limestones to arenaceous lime marl at the top.

The average increase in thickness of the Glen Rose bed from northwest to southeast along the Bosque section, is a little more than ten feet per mile. At Mount Airy, the Glen Rose bed is nearly fifty feet in thickness. At Alexander, fifteen miles east, it is about one hundred and fifty feet; at Iredell, thirty-five miles east of Mount Airy, it is four hundred feet; and at Walnut, ten miles further east, it cannot be less than five hundred feet in thickness.

If the beds of the Bosque division were restored, ten miles to the west of Mount Airy, under the conditions existing in the beds east of this place, the Glen Rose (Alternating) bed would disappear, and the Trinity sand would join with that of the Paluxy above. The outside horizons of the Alternating bed grade upward and downward into the Paluxy and Trinity sands respectively, and the upper portions of this bed, especially the marly bands, become thicker and the hard lime thinner toward the sand. Thin bands of shallow water shell-limestone extend into the sand, with thick bands of calcareous and sandy marl between them and the main bed of limestone.

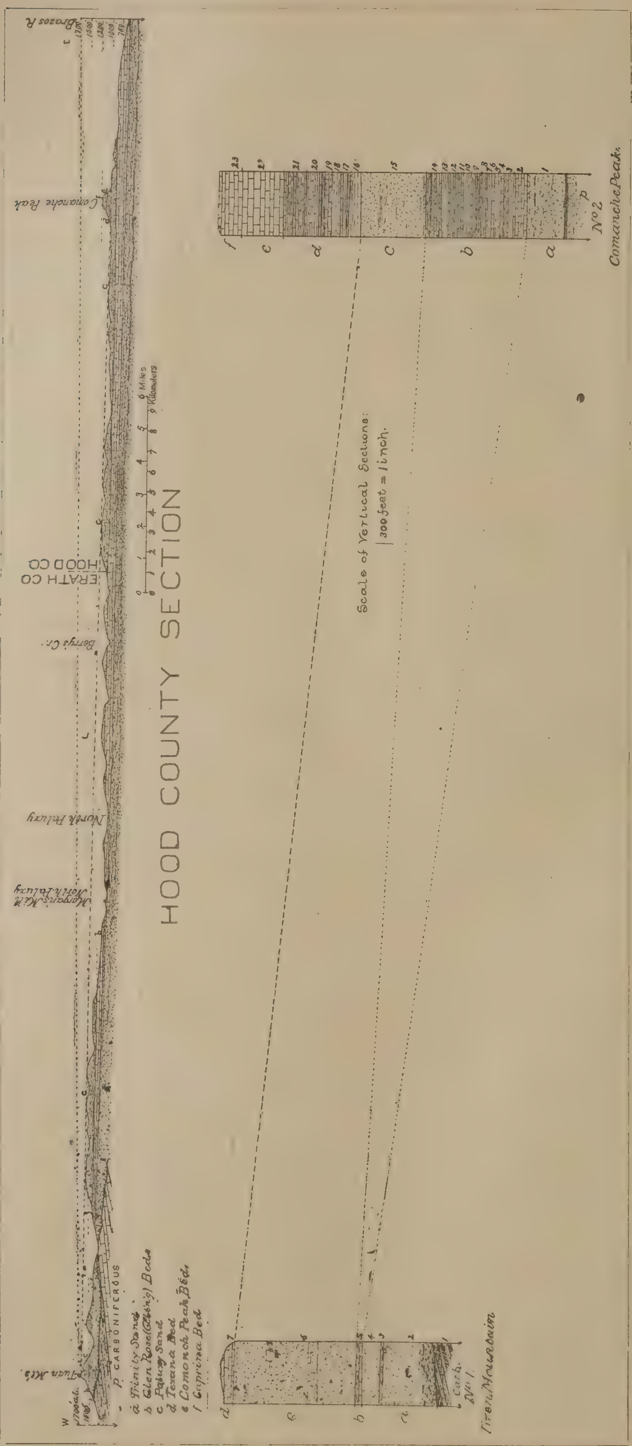
HOOD COUNTY SECTION.

This section extends due east from the Paleozoic at the base of Twin Mountains, near the western border of Hood county, across Comanche Peak to the Brazos river, near the east line of the county, and all of the beds of the Bosque division, together with the Texana, Comanche Peak, and a part of the Caprina, are included in it.

Special and detailed studies were made at Twin Mountains and at Comanche Peak, besides parallel work along the Paluxy valley from the head of Paluxy creek to Glen Rose, in Somervell county. This work was done by the writer in the season of 1889.

In 1890 Messrs. J. S. Stone and W. T. Davidson, under the direction of Mr. R. T. Hill, made a detailed section of the Glen Rose (Alternating) bed and Paluxy sand, with a portion of the Fredericksburg rocks. Their work in this section continued from the Trinity sand at Granbury to the top of Comanche Peak. The details of vertical Sec-

PLATE XII.


HOOD COUNTY SECTION
Brazos R.
Comanche Peak
ERATH CO
HOOD CO
North Paluxy
P. CARBONIFEROUS
a Trinity Sand
b Glen Rose (Alternating) Beds
c Paluxy Sand
d Texana Bed
e Comanche Peak Bed
f Caprina Bed
Scale of Vertical Sections:
300 feet = 1 inch.
No 2
Comanche Peak.
No 1

tion No. 2, Comanche Peak, are due mainly to the careful labors of Messrs. Stone and Davidson.

Carboniferous sands in thin shales and heavy gritty beds occur beneath the Cretaceous at the western base of Twin Mountains. The thin sand beds underlie the thicker grits; and these sand beds are in turn underlaid by Carboniferous encrinital limestone which outcrops in the valley east of the mountains. All of these rocks dip to the north or northwest. The same character of limestone was found beneath the Trinity sands of the Cretaceous north of Morgan's Mill, and also on the Brazos river above Thorp Springs, a fact which shows that they are of more than local occurrence, and that they continue probably some distance eastward beneath the Trinity along the line of the section.

NO. 1. TWIN MOUNTAINS SECTION.

1. Carboniferous sandstone resting unconformably beneath the Trinity, exposed . . . . 20 feet.

Trinity Bed.

2. Trinity sand . . . . 90 feet.

The lower twenty feet is a fine conglomerate of the same material as the conglomerate at the base of the Dublin section (see Plate XI). Siliceous brown, red, black and white pebbles, with sand and grit, constitute the basal portion. Few of these pebbles are more than one inch in diameter. The Carboniferous grit near at hand west of the Cretaceous border is the source of a part of the material of the conglomerate. The conglomerate is false-bedded, and in some instances changes rapidly from coarse to fine sand, thus indicating the action of strong and rapidly varying currents. The remaining seventy of the typical "packsand" of the Trinity bed, is false-bedded, pure and argillaceous yellow sand.

3. Arenaceous blue clay . . . . 3 feet.
4. Trinity "packsand" exactly similar to upper portion of No. 2 . . . 22 feet.

Glen Rose (Alternating) Limestone.

5. Limestone, slightly arenaceous, in thin ledges . . . . 5 feet.

Paluxy Sands.

6. Paluxy sand . . . . 190 feet.

This sand is fine-grained, yellow and generally friable. It readily disintegrates. Occasional partially indurated ledges are seen, but they are not of sufficient firmness to form benches on the mountain sides.

Texana Bed.

7. Sandy limestone, which contains *Exogyra texana*, *Gryphæa pitcheri* and *Cardium hillanum* . . . . 10 feet.

This limestone, the base of the Texana bed, forms the summit of the mountain.

NO. 2. COMANCHE PEAK SECTION.

Trinity Sand.

Along the Paluxy creek valley, from Morgan's Mill to Paluxy, Trinity sand occurs in exposures from the Glen Rose limestones downward to the bed of the creek. The base of the sand was not exposed. At Paluxy, Bluff Dale and at other points along Paluxy creek, many artesian wells have penetrated a band of stiff blue and red clay at a depth of from less than a hundred feet to one hundred and twenty-five feet. From the sand beneath the clay water flows abundantly from the well at the surface. This clay is no doubt a representative of No. 3 in the Twin Mountains section. In the upper portion of the Trinity bed great quantities of silicified wood occur along the Paluxy creek from Morgan's Mill to Paluxy postoffice. Whole trunks of trees are seen, some of which are three feet in diameter. In a ravine a short distance below Bluff Dale these silicified trees and fragments of logs are so abundant that one is reminded of drift wood, which doubtless they were at the time of deposition of the Trinity sands. Logs were seen here whose centers were silicified after having been first changed into lignite.

Glen Rose (Alternating) Limestone.

2.	Caprotina limestone, at the base of which Caprotina fossils are very abundant. These fossils are less numerous in the upper portion of the horizon	20 feet.
3.	Marly limestone, with an indurated layer near the center	16 feet.
4.	Bed of Ostrea—*Ostrea camelinis* (Cragin), *Ostrea franklini* (Coq.), and *Ostrea* sp. ind.	4 feet.
5.	Soft marly limestone	10 feet.
6.	Hard magnesian limestone, in which are small ferruginous segregations	4 feet.
7.	Soft argillaceous limestone, with thin indurated bands of limestone at the center and at the upper edge	8 feet.
8.	Marly limestone, changing gradually upward into harder limestone	8 feet.
9.	Marl and limestone alternating. The marly bands are from two to four feet thick, while the limestone is in thin layers	16 feet.
10.	Marly limestone	10 feet.
11.	Hard white crystalline limestone, which makes decided benches on the hillsides	4 feet.
12.	Four marly layers, from four to six feet in thickness, separated by three thin compact bands of limestone. A band of hard limestone caps the whole	20 feet.
13.	Marly limestone	12 feet.
14.	Thick arenaceous marly limestone and thin compact limestone in layers, the upper bands of which are sandy	23 feet.

Paluxy Sand.

15.	Sand bed	100 feet.

Near the upper and lower portions the sands become calcareous. The upper portion of No. 14 grades into the sand by alternations of sandy marls, sand and thin layers of limestone composed of small worn shell

fragments. Portions of the sand contain a considerable per cent of clay. Silicified wood occurs at many places in the sand. In physical appearance it is the same in character as that occurring in the Trinity beneath the Glen Rose bed.

Texana Bed.

16. Lime marl, with *Gryphæa pitcheri* . . . . 15 feet.
17. Marly and indurated limestone, with numerous *Exogyra texana* and *Gryphæa pitcheri* . . . . 18 feet.
18. Lime marls, with many *Gryphæa pitcheri* . . . . 14 feet.
19. Massive *Gryphœa pitcheri* bed. These fossils compose almost the whole rock mass . . . . 10 feet.
20. Argillaceous lime marl, with *Gryphæa pitcheri* at many places from the base to the top of the horizon . . . . 30 feet.
21. Marly limestone, in which occasional thin, partially indurated *Gryphæa* ledges occur. These thin layers contain many small *Gryphæa pitcheri*. The upper marly portion also contains many *Gryphæa pitcheri*, *Toxaster texanus*, *Cyprimeria crassa*, *Lima*, and *Exogyra texana* . . . . 34 feet.

Here at its culmination the *Exogyra texana* attains its greatest development.

Comanche Peak Bed.

22. Comanche Peak chalky limestone . . . . 66 feet.

There is little variation in the character of the rock throughout the Comanche Peak limestone. There are occasional more compact bands than are disclosed in the surface weathering; but as a whole, the bed is a massive chalky limestone. A glance at its surface on a slope is sufficient to determine its general character. More yielding than the Gryphæa and Texana marls beneath, and less persistent than the Caprina limestone above, it forms a narrow, gently sloping plane at the base, and favors acute topographic features, such as abrupt conical hills, truncate buttes, and abruptly sloping terraces, generally almost barren of soil. Where there is any vegetation on the exposed edges of these porous chalky rocks, the trees are dwarfed and the grass is coarse and worthless.

Caprina Bed.

23. Caprina limestone, compact, nearly pure limestone, varying but little from ledge to ledge, yet showing more distinct bedding planes than does the Comanche Peak limestone . . . . 33 feet.

Caprotina (*Requienia*) occurs throughout that portion of the bed which forms the summit of Comanche Peak. Precipitous bluffs almost invariably follow exposures at the lower portion of this bed.

CORRELATION WITH OTHER SECTIONS.

The peculiar characteristics of the three subdivisions of the Bosque formation, as illustrated in the Colorado and Bosque sections, are still more strongly emphasized by the details presented by the rocks of this section. The variation between this and the Bosque section is not

very marked, but when the rocks of this are contrasted with the same rocks on the Colorado, the change is striking.

The Trinity sand bed has no especial facies to distinguish it from the same bed on the Bosque river. Physically, structurally, lithologically, or paleontologically, there is no phase that will distinguish the rocks of the two localities. Every feature points to deposition under the same conditions. The same compressed porous fine sand in false beds, bearing the same flora, characterize each.

The Glen Rose lime marl series forcibly illustrates the structure brought out in the same rock on the Colorado and Bosque valleys. The evidence is, that all these beds (1) decrease in thickness toward the northwest and blend at the upper border with the Paluxy sand, and probably with the Trinity below; and (2) that the interstratified beds of marl become thicker and more friable toward the north. Beneath Comanche Peak these alternating lime marl strata are one hundred and fifty-five feet thick. Between Comanche Peak and Twin Mountains they decrease to five feet of arenaceous limestone (see section 1 plate XII). Five miles west southwest of Twin Mountains a thin calcareous sand, in Rattlesnake Mountain, is the only representative of the splendid development of limestone and marl, with its abundant and varied fauna. On passing westward along the contact of the Glen Rose lime marls, thin bands of shallow water shell lime are seen to pass into the calcareous sand, and to separate themselves from the beds below by varying thicknesses of sandy marl and calcareous sand.

The homotaxial relations existing between the Alternating and the Trinity beds grow stronger as the details of the two beds are brought to light. As was said of the Colorado section, in vertical section No. 2, the *Ostrea camelinis* (Cragin) occurs near the middle of the Trinity, between two beds of conglomerate. The same *Ostrea* appears at the base of the Glen Rose series in the Bosque section. In the Comanche Peak section of Hood county the same form, as determined by Professor Cragin, occurs thirty-six feet above the base of the Glen Rose lime marls. (See No. 4 of Comanche Peak section.) Whether or not the *Ostrea* occurring at these three separate localities belong to one continuous bed, it is not now possible to say from a stratigraphic point of view; but in the light of this evidence, and in view of the structural details presented in the Colorado section, there is no doubt that parts at least of the Trinity sands and Glen Rose lime marls are representatives of each other.

As the Glen Rose bed thins going westward, the Paluxy sands increase in nearly the same proportion. Beneath the base of the Texana bed in Comanche Peak, the Paluxy sand continues downward one hundred feet. The same sand bed forms one hundred and ninety feet in the upper portion of the Twin Mountains. As at every other locality noted the Texana bed rises abruptly from the Paluxy sands.

THE COLUMNAR SECTIONS.

The columnar sections on Plate XIII were made along a line nearly north and south from Hiner, near the Brazos river, to St. Joe, near Red River. They are drawn to scale, that the relations of the different beds, their structure and variation, may be easily perceived.

The adjustment of the sections upon the plate has no reference to their relative elevations above tide level.

HINER SECTION.

This section was made from the base of the Trinity river, Hiner post-office, to the top of the Texana beds, near Pleasant Point church, in southern Parker county. Beneath the Trinity sand, between Millsap and the Brazos river, there occur red and blue clay, and pale blue fissile sandstone, which presumably belong to the Carboniferous formation* beneath; the Trinity sand rests unconformably upon them.

TRINITY SAND.—The Trinity sand occurs in good exposures along a run three-fourths of a mile southeast of Hiner. It is beautifully false-bedded and false-laminated, and shows clearly the action of the waves and fluctuating currents. From the base upward, about twenty feet, worn siliceous pebbles of various sizes and colors compose a great part of the material, as was seen also at the base of the Dublin and Twin Mountains sections.

Near the upper portion of this gritty pebbly bed, there are fragments of silicified wood, which is very common here near the middle of the sand. Above the zone of fossil wood the sand becomes argillaceous and calcareous, indurated in bands. Here are also local deposits of purple and red sandy clay, and nodules of iron sandstone occur quite abundantly in the upper half of the sand. In a gulch in Kidwell's pasture, near the Milligan ranch place, two miles east of Hiner, there is an exposure of sand, clay, lignite and silicified wood. This is fifty feet below the upper limit of the Trinity sand. The lignite is local, and appears to have occupied at one time the bed of a lagoon. Limbs, fragments and bodies of trees project from the bluff, lignitized and silicified. In some instances the lignite has been silicified. In the case of a large tree, the central portion was silicified to within a few inches of the circumference, where silicified wood gave place to silicified lignite, which continued to a narrow outside rim of lignite.

GLEN ROSE BEDS.—The Trinity sand grades upward into the Alternating beds through about twenty feet of calcareous sand.

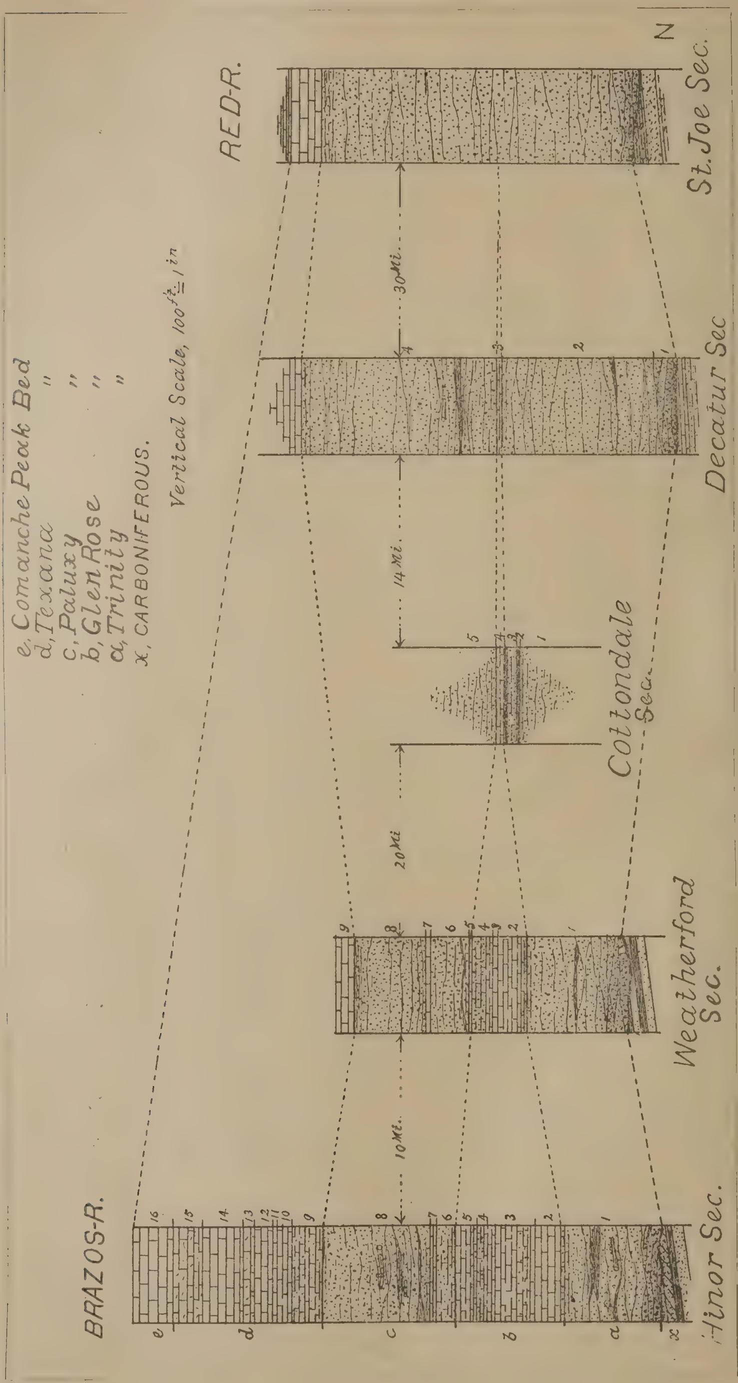
1.	Trinity sand	100 feet.
2.	Cardium bed	30 feet.

This bed is composed almost wholly of casts of *Cardium mediale*, *Natica*, *Cyrena*, *Goniolina*, and many other undetermined fossils.

3.	Alternating hard and crumbling limestone	50 feet.

*Geological Survey of Texas, Second Annual Report, pp. 372 and 381.

PLATE XIII.


e, Comanche Peak Bed
d, Texana "
c, Paluxy "
b, Glen Rose "
a, Trinity "
x, CARBONIFEROUS.
Vertical Scale, 100 ft. = 1 in.
BRAZOS-R.
RED-R.
N
St. Joe Sec.
Decatur Sec
Cottondale Sec.
Weatherford Sec.
Hinor Sec.
30 Mi.
14 Mi.
20 Mi.
10 Mi.

There are indications of fossils in this bed, but no complete forms were seen.

4.	Marly and shaly lime, with numerous *Cardium*, *Arca*, *Cyrena*, *Trigonia*, *Anomia* and *Ammonites*	10 to 15 feet.

This is the same horizon, lithologically, and contains identically the same species of fossils as that which crops out in the banks of the Bosque river at Iredell, Bosque county; and the relative position of the horizons above and below is very nearly the same in each locality.

5.	Marly and shaly limestone, capped by a ledge of hard crystalline limestone	20 feet.
6.	Calcareous yellow sand, stratified	20 feet.
7.	Yellow crystalline limestone, made up of shell fragments	5 feet.
8.	Paluxy sand bed	110 feet.

This sand varies but little lithologically between the transition rocks at the upper limit of the Alternating and at the lower edge of the Texana beds. There is no perceptible difference in any respect between this sand and that of the same bed at the base of the Comanche Peak, or in the valley of the Bosque river. Fragments of silicified wood are occasionally met with in the Paluxy sand here.

TEXANA BED.—There is about ten feet of limy sand marl, which may be considered to form part of both the Paluxy and Texana beds.

9.	Marly limestone, containing very many *Exogyra texana*, *Gryphæa pitcheri* and *Ammonites*	30 feet.

Nearly ten feet of the upper portion is composed almost wholly of the fossil *Gryphæa*.

10.	Chalky limestone, with few *Gryphæa*	15 feet.
11.	Hard limestone, with many small *Gryphæa*	1 foot 6 in.
12.	Chalky limestone	1 foot 8 in.
13.	*Gryphæa* shell limestone	10 feet.

The fossil *Gryphæa pitcheri* is dwarfed to at least one-half of the size of those in the lower portion of the bed.

14.	Hard chalky limestone	40 feet.
15.	Chalky limestone, with large *Exogyra texana*, *Toxaster texanus*, *Lima* and *Cyprimeria crassa*	30 feet.
16.	Comanche Peak chalky limestone	40 feet.

WEATHERFORD SECTION.

This section was made between Millsap and Weatherford from the base of the Trinity upward.

The Trinity sand rests unconformably upon a variegated blue green and deep red clay, in a run where the south Weatherford and Millsap road crosses the contact. At a somewhat lower elevation, and not far west of the clay exposures, fissile hard sandstone and bluish clay were seen, dipping at an angle nearly five degrees toward the west. A pebbly grit and gritty sand forms the basal portion of the Trinity, from the contact with the clay upward for twenty-five feet, as in the Hiner,

Twin Mountains and Dublin sections. Portions of this grit are indurated in irregular beds. In the upper portion of the sand, yellowish and purplish yellow calcareous nodules are common, some of which are cut by cavities and contain bands of calcite septaria.

1. Trinity sand from Carboniferous clay to Glen Rose (Alternating) series . . . . 105 feet.

Glen Rose Bed.

2. Arenaceous marly lime and hard crystalline shell limestone, alternating . . . . 30 feet.

Cardium mediale, *Turritella*, *Anomia* and *Pleurocera* are numerous. Many Cyrena-like fossils occur in hard calcareous sand at the base of the Alternating rocks. The greater part of the fossils are in the form of casts, as is the case elsewhere in these rocks, a fact which makes their identification difficult.

3. Arenaceous limestone, indurated . . . . 5 feet.
4. Sandy lime marl, sandy at upper edge . . . . 18 to 20 feet.
5. Crystalline shell limestone . . . . 1 to 2 feet.

Immediately above and below this limestone, as well as in the limestone, are many small *Exogyra* sp. ind., *Turritella*, *Cardium*, *Anomia*, *Serpula*, etc. These fossils occur in the greatest profusion in the banks of the creek one-half mile northwest of the Texas and Pacific depot at Weatherford. The crystalline limestone is not continuous, but occurs as lenses and lenticular bands in the false-bedded sand. Immediately below this *Exogyra*, there are fragments of bone and teeth.

Paluxy Bed.

6. Yellow packsand . . . . 40 feet.
7. Crystalline limestone composed of shell fragments in lime matrix . . . . 5 to 8 feet.
8. Yellow "packsand" . . . . 70 feet.
9. Texana bed, exposed . . . . 20 feet.

Gryphæa pitcheri and *Exogyra texana* in great abundance.

From a comparison of the details of these two sections, north of the Brazos river, is becomes apparent that the Glen Rose beds thin rapidly from the first at Hiner, due northward to the second at Weatherford; but that the disintegration of the rocks of this bed is not so great northward as it is in the same bed westward in Hood county.

The Glen Rose (Alternating) beds are represented at Springtown, along the banks and valley of Walnut creek, by a few thin bands of shell limestone with intermediate thick layers of calcareous sand. There are good exposures of these rocks one and two miles south of Cottondale, in Wise county. Two miles south of Cottondale, on the west side of the Springtown-Cottondale road, in the sand, are thin bands of crumbling arenaceous limestone, which contain *Cardium hillanum*, *Cardium mediale*, *Trigonia crenulata*, and the small *Exogyra*

texana. Calcareous argillaceous sand continues downward grading into the Trinity sand.

On the south side of Salt creek, one mile south of Cottondale, there are small buttes and terraces caused by the presence of the Alternating beds along the edge of the flood-basin of the creek.

Below is a section of the Alternating series, beginning at the base:

1. Trinity sand . . . .
2. Fossil leaves and wood; wood in fragments and leaves in thin, irregular sheets . . . . 1 to 6 inches

The wood is lignitized in the form of fragments of logs and branches.

3. Calcareous sand, stratified and false laminated . . . . 10 feet.
4. Arenaceous limestone, with numerous *Ostrea*, *Anomia*, *Trigonia crenulata*, *Cardium hillanum*, *Cardium mediale* (?), *Cyrena*, *Serpula* and occasional small *Exogyra texana*, and gasteropods . . . . 10 feet.
5. Paluxy sand, calcareous near the base . . . .

Four miles west of Cottondale there is a local bed of fibrous calcite, from three to eight inches thick; above it are layers of friable and indurated sandstone. The calcite belongs at the base of the section.

DECATUR SECTION.

From the base of the Trinity to the Texana bed in the town of Decatur, Wise county.

Across Wise county moderately hard sandstone and shale of the Carboniferous period form the bed of the Cretaceous.

TRINITY SAND.—A zone of pebbly sand rests uncomformably upon the Carboniferous sand, forming the foundation of the Trinity, as at other related points south of the Brazos river. The volume of pebbly material grows less on ascending the sand, until it altogether disappears, and is succeeded by fine "packsand." Silicified wood is present in the basal portion, but it does not occur so abundantly as in Hood county and at other points further south. In character, however, the pebbly sand is identical with that in the same beds noted above.

1. Basal pebble zone . . . . 20 to 30 feet.

Satisfactory exposures of the Trinity sand, in situ, are very rare. The grade of the country toward the Trinity river becomes less steep, and the valleys of the streams wider, as one descends from the Paluxy sand and Glen Rose rocks. Instead of having bluffy banks and steep inclines, like the topography of the Paluxy bed, the surface is gently rolling, and the streams wind sluggishly between low banks of transported sand. In the upper portion of the Trinity sand there are local patches or collections of argillaceous lime nodules, yellow to pale red in color, some of which are intersected by a network of calcite septaria. Small glades open the forest where these nodules occur in quantities on the surface. Silicified wood is sparsely scattered through this sand.

2. Trinity "packsand" . . . . 160 feet.

GLEN ROSE (ALTERNATING) BED.—On Walnut branch, about four miles southwest of Decatur, and nearly two hundred feet below the summit of the Paluxy sand, calcareous indurated and friable sands occur. The soft layers are nearly pure sand. In one of the indurated ledges there are many *Anomia*, *Cyrena* (?) and casts of gasteropods. These alternating compact and soft layers of calcareous and pure sand are not more than ten feet thick.

On Isbel branch, about three miles northwest of Decatur, and one hundred and eighty feet below the summit of the Paluxy sand, "packsand" with thin bands of light blue impure clays are extensively false-bedded, and in some instances minutely cross-laminated. At about this elevation, and associated with the argillaceous sand, there is indurated calcareous sand in thin ledges with "packsand" surrounding it. These indurated ledges contain *Anomia*, *Cardium*, *Cyrena* and gasteropods.

On Watson's branch, one-fourth mile east of the Fort Worth and Denver Railway, this same bed crops out in an irregular band of calcareous sand, which contains bivalves and gasteropods. The zone of calcareous sand is not continuous, but occurs as wedges and lenses of fossiliferous rock in false-bedded strata. The fossils are casts. The Glen Rose beds have not been observed north of this locality in Texas. These rocks, which at other places form so important a part of the geology and topography, and which give many thousand square miles of surface exposure in Central and Southern Texas, dwindle here to a span of strata, and were it not for its fauna and direct continuity with the southern area, its geologic position would be hardly suspected.

PALUXY SAND.—"Packsand," with now and then a thin band of calcareous sand, associated with porous nodules in bands, occurs on Walnut branch, one hundred and seventy feet beneath the top of the sand. Ten feet below this point "packsand" crops out in irregular bands of argillaceous sand.

These sands and sandy clays are false-bedded, and contain lenticular bands of carbonaceous sand and lignite. The lignite occurs as fragments of trunks and branches of trees, all of which show most beautifully the structure and fibre of the original wood. Good exposures of this sand occur along Isbel branch, below the Fort Worth and Denver Railway. One hundred and twenty feet below its upper layers it becomes saline, and on exposure in the banks of the run common salt in small quantities is found. This saline sand contains a good per cent of impure clay, and beneath it occurs the irregular band of calcareous sandy nodules. Beginning on Watson branch, a short distance east of the Fort Worth and Denver Railway, excellent exposures continue until the top of the sand is almost reached. Often the bluffs are from forty to fifty feet high, and exhibit most beautifully the cross-bedding of the sand with impure clays, lignitic sand, lignite and silicified wood. The ignite exhibits the same characteristics here as it does elsewhere. It

occurs in fragments, in thin lenticular bands, and is alternately stratified or laminated with lignitic and pure sand. Fifty feet beneath the summit the Paluxy sand becomes calcareous. It is fine-grained and comparatively homogeneous, and in places indurated. At Decatur the Texana bed rests upon calcareous sandy marl a few feet thick, which grades downward into an argillaceous sand, in which are local deposits of impure red and blue clays. At other places the Texana limestone rests directly upon clear sand.

3. Paluxy sand . . . . 200 feet.

The Texana marly lime and marl occurs, differing not materially from that at Weatherford, Comanche Peak and Dublin or Walnut. The town of Decatur rests upon the bed. The total depth was not determined.

BOSQUE AND ASSOCIATED ROCKS AT ST. JOE, MONTAGUE COUNTY.

The contact of the Cretaceous and Paleozoic rocks passes near Bonita in a general north and south direction. Red clay and fissile brown and red sands form the bed rock of the Cretaceous.

TRINITY SANDS.—A conglomerate of pebbles and sand forms the basal zone of this sand, as is the case at other localities cited above. Beginning in northern Wise county, large masses of an indurated conglomerate appear at the base and so continue through Montague county to Red River valley. The easily eroded "packsand," where areas had been detached by erosion, envelop large masses of this hard conglomerate, which is believed to be pre-Cretaceous. In compact masses similar pebbles occur, mixed with the sand, associated with the erratic compact conglomerate. Above the pebbly zone, through a vertical distance of three hundred and twenty feet to the Texana limestone, there is no perceptible change in the sand. In the character of the material composing the sand and of the structure there is no indication of a change or cessation of deposits throughout the bed. There is, undoubtedly, a representative of the Glen Rose (Alternating) bed in the central portion of these sands, but it is no less clearly evident that the subsidence, during which the alternating marls and limes were deposited, did not carry the then coastal area between St. Joe and Decatur to a sufficient depth for the deposition of calcareous rocks until after the completion of the Paluxy sands.

TEXANA AND COMANCHE PEAK BEDS.—A zone of semi-crystalline white limestone in heavy beds, about thirty feet in thickness, here represents the Texana, Comanche Peak, and Caprina beds, which are so extensive south of the Brazos river.* The flints disappear from the Caprina bed near its passage across the Brazos river, as also do the

* "Goodland" limestone of Hill. See Bulletin Geological Society of America, page 514.

flaggy and siliceous layers. The marly bands of the Texana and the friable chalks of the Comanche Peak beds have representatives here in compact sub-crystalline limestone.

Though the rocks of these beds thin out to a mere fraction of their former thickness, yet in part at least the fossil fauna remains, and in spite of its great decrease in volume, serves as an unfailing proof of the identity of the stratigraphy.

Two miles east of Benbrook, on the Texas and Pacific Railway, and eight miles west of Fort Worth, this limestone is two hundred feet thick, carrying the numerous and varied fauna of the Texana and Comanche Peak limestone in greatest abundance.

Beginning with the crumbling chalky limestone of the Comanche Peak at this point, and with the massive semi-crystalline limestone on Red River at a sharply marked division line stratigraphically, a series of blue plastic clays, interstratified with thin bands of flaggy limestone and massive Gryphæa rock, rise to a vertical height of thirty feet. The conformability of these (Kiamitia) clays with the chalky limestone at the south, and the hard limestone at the north, is complete, but the stratigraphic and lithologic line of demarcation between them is striking.

The details of these rocks will be brought out more fully in a discussion of the Comanche series at Goodland, Indian Territory, and at Denison, Texas.

THE BOSQUE DIVISION AND ASSOCIATED ROCKS WEST OF THE MAIN CRETACEOUS BORDER.

During a part of the season of 1889 the writer studied and outlined the Cretaceous remnantal outliers west of the main Cretaceous area. As an aid in this work, a pedometer, a compass and an aneroid barometer were used. The barometer was employed only for local work, such as making vertical sections of mountains, and for local correlation of strata.

Special studies were made of the rocks of this division, the Paleozoic rocks below and the Fredericksburg division above, at:

1. Baker Mountain, which is one of a collection of buttes in the corner of Callahan county called the Savannah Hills, and which is a member of the unbroken arm of Cretaceous rock extending from the main area in Comanche county to Pecan bayou, south of Belle Plains.
2. Buffalo Gap, on the west side of Elm Fork of the Brazos.
3. Castle Mountain, at the mouth of Mulberry canyon, near the line of Taylor and Nolan counties.
4. Bitter creek, south of Sweetwater, Nolan county.
5. Horse Mountain, one of a group of buttes on Yellow Wolf creek, upon the north side of Colorado valley, in Coke county.
6. At Church Mountain, in the southeast corner of Nolan county.

(1). BAKER MOUNTAIN SECTION.

A waste of Trinity sand surrounds the base of this mountain and the surrounding buttes to a distance of seven miles, forming what is locally known as "sand roughs," which are areas of undulating surfaces or loose sands, overgrown with a thick forest of "shin-oak." The valley lands of the small streams that rise in these sands and flow into the tributaries of the Brazos or Colorado rivers are quite productive and afford farms for a considerable population. Wells sunk in the sand at the base of Baker Mountain penetrate to Paleozoic limestones and clay at fifty to sixty feet.

Section of Baker Mountain from base upward:

1. Porous homogeneous "packsand" . . . . 95 feet.
2. Coarse gritty sand . . . . 15 feet.
3. Stratified, partially indurated, calcareous sand, which weathers in rough nodular porous masses . . . . 50 feet.
4. Red and purple clays, locally distributed. In some places it is ten and more feet in thickness; at others it is absent. Total thickness of sand . . . . 160 feet.

The Glen Rose (Alternating) beds are absent, and the sands are unbroken from the Paleozoic to the Texana bed, which succeeds the sand.

5. Calcareous indurated sandstone, grading upward into marly or arenaceous crumbling limestone, bearing small *Exogyra texana*, *Gryphœa pitcheri*, and associated fauna of the Texana bed, such as *Ammonites Toxaster*, *Natica*, and *Cardium* . . . . 20 feet.
6. Comanche Peak limestone, with probably the basal portion of the Caprina limestone . . . . 110 feet.

(2). BUFFALO GAP SECTION.

Elm Fork of the Brazos river, flowing northward, and the Jim Ned creek, tributary to the Colorado river, on the south, have cut through the Cretaceous rocks down two hundred feet into the red clays and fissile sandstone of the Permian strata, and have formed the pass of Buffalo Gap, leaving the almost perpendicular side-walls of Cretaceous rock on truncated bases of the Permian.

1. Trinity sand, having the general character as the corresponding rock in Comanche and Erath counties; fine grained and compact, but not indurated, bearing evidence of changing, but not extremely variable current action in its structure; near the base tinged with red clay, and in some cases may contain bands of clay from the Permian strata. From this strata most of the sand at least has its origin. The depth of sand here is . . . . 140 feet.
2. Texana bed, composed of stratified arenaceous limestone in thin layers, bearing small *Exogyra texana*, *Gryphœa pitcheri*, *Pecten* and casts of small bivalves . . . . 2 to 4 feet.
3. Heavily bedded Comanche Peak limestone, succeeded by twenty or more feet of massive Caprina limestone . . . . 130 feet.

(3). CASTLE MOUNTAIN SECTION.

On the east side of the entrance to Mulberry canyon, two peaks, formed by Castle Mountain and East Mountain, composed of Cretaceous and Permian rocks, remain isolated from the body of the table land, into which Mulberry creek has worn its canyon and its many fingered gorges. The creek has long since passed beneath the base of the Cretaceous rocks, and is now imbedded two hundred feet in the Permian strata along the side of Castle Mountain. Perpendicular bluffs from forty to sixty feet high near the summit of the peak give excellent exposures of bedded calcareous sandstone and limestone.

The following section of the mountain was made from the base upward:

1. Red beds of Permian sandstone and clay, from bed of Mulberry creek to base of Cretaceous sand . . . . 200 feet.
2. Trinity or Paluxy sand, or both . . . . 60 feet.

There seems to exist no variation between this sand and the corresponding bed, No. 1, of the Buffalo Gap section.

3. Stratified and very slightly indurated calcareous sand, bearing in the upper edge Texana and Comanche Peak bed fauna . . . . . . 20 feet.

It contains small *Exogyra texana*, *Grpyhœa pitcheri* forms with associated fossils.

4. Comanche Peak limestone, arenaceous in the lower portion . . . . . 40 feet.

(4). BITTER CREEK (NOLAN COUNTY) SECTION.

Along the east side of Bitter creek valley there are precipitous bluffs which exhibit excellent exposures of Permian and Cretaceous rock in successive strata.

1. Permian red sandstone, from base of Bitter creek upward to the base of the Cretaceous bluffs . . . . 110 feet.
2. Cretaceous conglomerate, of loosely cemented siliceous pebbles of various tints and colors of red, brown and black. It resembles the pebbled conglomerate grit at the base of Dublin section . . . 10 feet.

Fragments of indurated conglomerate occur in the red beds at the contact and in the loose conglomerate of the Trinity.

3. Trinity or Paluxy sand . . . . 120 feet.

The sand is similar to that at Buffalo Gap and at other localities further east in the same bed, except that at near the base at Bitter creek, where it exhibits reddish and in some instances a purple hue. This color seems to have its origin in the almost similarly colored beds of the Permian.

4. Limestone, in thin layers, sandy at the base. This bed is believed to represent the Texana bed. Texana fauna occurs near the contact of the sand and limestone . . . . 15 feet.
5. Massive chalky limestone, of the Comanche Peak subdivision . . . 20 feet.
6. Limestone, in thin beds . . . . 15 feet.

From Bitter creek the Cretaceous escarpment continues toward the

west, bearing the strata of this section about fifteen miles, when it is overlapped and concealed by post-Cretaceous (probably Quaternary) conglomerates and calcareous bluff marls.

(5). HORSE MOUNTAIN SECTION.

The conditions here, on the south side of the plateau, are the same as they are on the north side. Yellow Wolf creek has, by its erosion, cut through the Cretaceous strata and is now far down into Permian "Red beds." Cretaceous capped buttes and conical hills stand about in the canyon, and on each side, where horns projecting from the plateau have been severed by erosion.

Horse Mountain is a member of this group of buttes.

1. Red Permian sandstones, from the bed of Yellow Wolf creek to the base of the Trinity sand . . . . 80 feet.
2. Trinity or Paluxy sands, slightly indurated in places . . . . 160 feet.

The basal portion is tinged with red and purple from the Permian. Local collections of pebbly conglomerate occur at the contact.

3. Comanche Peak limestone, with Texana bed fauna at the base . . . 100 feet.
4. Massive chalky limestone, bearing bands of large flint nodules near the center. It generally forms impassable bluffs around the cap of the mountain . . . . 60 feet.

(6). CHURCH MOUNTAIN SECTION.

Church Mountain is one mile out from the point of the long Cretaceous promontory, which extends southeastward from the plateau between the canyons of Oak and Fish creeks.

Since the early settling of the country, this peak has been a noted landmark on account of its isolation, height and peculiar shape. It is oblong and sharp, and is crested with a tall spire-like point of rock at the southwest end.

1. Permian red sandstone, with a zone of quartzitic brown sand at the top . . . . 80 feet.
2. Trinity or Paluxy sand, with a border of pebbly sand at the base in contact with Permian rocks . . . . 90 feet.
3. Comanche Peak limestone, with Texana bed fauna in contact with the Trinity . . . . 80 feet.
4. Massive chalky limestone . . . . 20 feet.
5. Compact bedded limestone . . . . 30 feet.
6. Massive chalky limestone, containing flint nodules in considerable quantities . . . . 25 feet.

The limestones of Nos. 4, 5 and 6 are considered to constitute the Caprina bed.

CORRELATION OF THE TRINITY, GLEN ROSE AND PALUXY BEDS.

That the Trinity sand is Cretaceous, and represents the littoral deposits of a part of the Lower Cretaceous series, has evidence in the facts that its beds abut against the pre-Cretaceous continental contour;

that its beds conform to and blend with the undoubted Cretaceous Glen Rose limestones; that its component materials are local and have their origin in the Paleozoic as a strictly near-shore rock; and further, that it contains fossil fauna and flora that range through superimposed beds of sand and limestone.

Along a line drawn from the Colorado river at the Burnet-Travis county line to Naruna, Burnet county, a distance of less than forty miles, the Trinity occupies a Paleozoic contour, ranging at an elevation of from six hundred and fifty to fifteen hundred and fifty feet above sea level. As this line is followed from the river northward, the Trinity conglomerate and sand may be observed to vary in thickness and component material, which variation is governed in a measure by the underlying contact rock. Lenticular beds of conglomerate and sand are seen to extend away from the Trinity bed, to blend into the strata of the Glen Rose limestone above, and to become calcareous sand and siliceous limestone inseparable from the Glen Rose beds. Near the Colorado river there are four hundred feet of Glen Rose strata; above the Trinity at Burnet there cannot be more than two hundred feet; while at Naruna there is less than one hundred feet of these limestones. Thus it is clear that the conglomerates and sands of the Trinity pass upward gradually into the Glen Rose (Alternating) beds, representing the shore debris during the formation of a great portion of these limestones.

In the shell limestone included in the Trinity of the Colorado valley there occur *Trigonia crenulata* and *Ostrea camelinis* (Manuscript of Cragin). The *Trigonia* ranges as high as the Comanche Peak limestone, and the *Ostrea* is found in the Glen Rose beds as seen at Granbury and in Erath county west of Mount Airy.

There is no perceptible difference in the fossil woods which occur in the Trinity and Paluxy sands.

The Glen Rose beds present the form of a wedge, with its edge toward the northwest, between the Trinity and Paluxy sands. Erosion has cut gaps in the edge of this wedge-like formation from Decatur, Wise county, to the western portion of Erath county, near Twin Mountains. From Twin Mountains the edge or western line passes very near the northwest corner of Comanche county and on toward the south through the eastern part of the Central Mineral Region.

When the shore of the lower Cretaceous sea had reached a point not far west of the line given above, for the restored western limit of the Glen Rose beds, there was a cessation of the continental subsidence in this region, and after a time there was probably a slight elevation, after which the profound subsidence of the Lower Cretaceous continued. At the beginning of the cessation of the continental subsidence the sands were laid down on the surface of the recently formed Glen Rose limestone; and when the shore moved eastward, the sands were carried further out. Meanwhile, off-shore marls and shell

limestone, were being formed, and as the shore fluctuations or changes of currents came, near-shore limestone and sandy marls interlapped. This interlapping is illustrated along the edge of the Glen Rose and Paluxy beds in a great many localities.

It seems most probable that there was a cessation in the downward continental movement, and an increase of land erosion and seaward current action, rather than an elevation of land along shore, for the reason that the Glen Rose beds were not exposed between the times of the deposition of the Trinity and the Paluxy sands. If there had been an elevation of the land to any great extent these limestones would have been exposed and eroded, for they are not of deep sea formation. In spite of these evidences, showing that there was but little or no elevation of the land at this period, there are indications of variable and shallow current action in the false-bedding of the Paluxy sands many miles east of the western point of the Glen Rose limestone.

The manner of contact of the Paluxy sand and Glen Rose beds alone is sufficient evidence of their relations. From the western border of the Glen Rose beds, where the limestone has tapered to a narrow band, and where the Paluxy sand is one hundred feet thick, to the east, where the sand has decreased to a few feet and the limestone has developed into an extensive bed, the limestone along the contact extends out into the sandy marl in thin ledges of worn shell rock, and there discontinue blending with the arenaceous marl. This transition marl and calcareous sand with diminishing shell flagstones along the Paluxy-Glen Rose contact reaches a thickness in some instances of thirty feet.

II. THE LAMPASAS-WILLIAMSON SECTION

WITH THE

GEOLOGY OF PORTIONS OF LAMPASAS, BURNET, AND WILLIAMSON COUNTIES.

INTRODUCTION.

This work includes in its scope the whole of the Cretaceous system of Central Texas, over a typical area beginning at the base west of Nix postoffice, in Lampasas county, and passing southeast to the top of the system east of Copeland and Thorndale, in Travis and Milam counties respectively.

AREA.—It was not considered expedient, for lack of time and other reasons, to consider areas in this work, further than was necessary for a full study of the geology—stratigraphic and economic. The partings between the beds are so clearly marked by natural stratigraphic and topographic lines, and there is so little variation in the geology north and south along any rock bed, it was rarely necessary to work in those directions more than ten miles. When the study of a bed is complete for this range it is complete for the adjacent region.

THE SECTION.—The Lampasas-Williamson section begins west of the Carboniferous-Cretaceous contact, about two miles north-northwest of Nix, in Lampasas county, and extends in a general southeast direction to the Tertiary border near the junction of Travis, Williamson and Bastrop counties. It passes through Nix, Lampasas, Bachelor Peak, Pilot Knob, Georgetown, Hutto, and crosses Brushy creek below Rice's crossing.

The profile of the section from Lampasas to Hutto was obtained from a line of levels run with transit and stadia by the Survey, from the western terminus to Lampasas, and from Hutto to the Tertiary border it was obtained from the United States Geological Survey topographical sheets.

The section is projected on an east-west base line, and is drawn on a scale of one inch to two and forty-two hundredths miles. The ratio of the vertical to the horizontal scale is as eight to one.

As stated, the section extends entirely across the Cretaceous area, and as the rocks dip toward the southeast, it is perpendicular to their strike; a complete section is thus obtained, both the lower and Upper Cretaceous rocks being shown.

The geology was worked systematically, reference being made when necessary to each instrument station. In this manner the Lampasas-Williamson section was made with its detailed vertical sections. Parallel studies were made along the tributaries of Sulphur, Mesquite, Rocky, and Brushy creeks and San Gabriel river, verifying the work upon the section line.

Another object also of the section was to obtain reliable estimates for boring artesian wells in the artesian basin of this region.

The beds, which are represented upon the section by the letters *a* to *k* inclusive, extending from the Carboniferous contact to a point about two and one half miles southeast of Georgetown, are Lower Cretaceous; those which are represented by *aa*, *bb*, *cc*, etc., are Upper Cretaceous. The following scheme will give a concise view of the divisions and subdivisions occurring in this section:

Upper Cretaceous		dd.	Blue (Ponderosa) marl.
		cc.	Austin limestone.
		bb.	Eagle Ford shale.
Lower Cretaceous	Washita Division	l.	Vola limestone.
		k.	Arietina clay.
		j.	Fort Worth limestone.
	Fredericksburg Division	i.	Kiamitia.
		h.	Austin marble.
		g.	Flag limestone.
		f.	Caprina limestone.
		e.	Comanche Peak limestone.
		d.	Texana limestone.
	Bosque Division	c.	Paluxy sand.
		b.	Glen Rose (Alternating) limestone.
		a.	Trinity sand.

THE MAP.—A much larger area is included in the map accompanying this report than was studied in detail during the field season, but the contacts between the divisions have been located by the Survey with the exception of the line between the Bosque and Fredericksburg divisions.

Lack of time alone prevented the location of this parting line. The contact between the subdivisions of the Washita division were traced and appear upon the map.

The base of this geological map was adopted from the United States topographic sheets of the region. These topographic sheets were of very material aid in the prosecution of the geological field work. It was not expected that they would serve the purpose of a closely detailed map, but for one with a contour difference in elevation of fifty feet they were bound to be quite satisfactory.

STRATIGRAPICAL GEOLOGY.

The Cretaceous border* across Lampasas county marks very nearly the summit line of the hydrographic basin of the Colorado river, which

*This border line was traced by the writer in the spring of 1889 under the direction of Mr. R. T. Hill, who then had supervision of the Cretaceous area. Further investigation in the past season was made upon the Paleo-Cretaceous border in the vicinity of Nix, at the beginning of the field-work at this section, by the writer in company with Mr. S. Leverett.

runs six to fifteen miles to the southwest of it, hence the drainage from this border is downward over the Paleozoic. The principal tributaries to the Colorado river in Lampasas county are Lynch, Salt and Antelope creeks.

Near the mouth of Lynch creek, and further south along the Colorado river valley, hard blue marble and lithographic flagstones occur beneath Carboniferous strata which are most probably of Silurian age.

Dr. Comstock, in the First Annual Report of the Geological Survey of Texas, page 301, says: "Upon the northern border of our portion of the Central Region the Cretaceous overlies the Carboniferous, and a broad area of high Silurian is now uncovered in that region." In the same report, under the head of "Devonian System," he says: "At several points along the northern border of our district (the Central Mineral Region) the contacts of the Silurian (San Saba series) with overlying beds are different from what has been reported elsewhere, and not what I have observed in other places. Between what Mr. Cummins and Mr. Tarr, as I understand them, assume for the Siluro-Carboniferous contact in the region above the southwest corner of Lampasas county, there is in some sections an important series of strata of but little thickness, but containing fossils closely allied to Devonian types."

From Dr. Comstock's description of the supposed Devonian rocks it is most probable that this "marble" and "lithographic" limestone does not belong to them.

In the Second Annual Report of the Survey, p. 568, he himself expresses doubts as to his supposed Devonian being a member of that system. The contact between these crystaline blue limestones and flaggy lithographic limestone strata was observed nearly five miles west of Nix, near the Colorado river. The contact passes from this locality in a southeasterly direction to the Cretaceous border near the line of Lampasas county. The exact point where this Siluro-Carboniferous contact passes beneath the Cretaceous was not seen, but the rocks of the Silurian system were observed south of the county line, and those of the Carboniferous north of it.

Two miles south of Nix, the Carboniferous limestones pass from the Cretaceous border, with northeast strike, through the junction of the two branches of Lynch creek three miles west of Nix. The limestone dips northeast about ten degrees.

Sandstone, ferruginous and in flaggy and false-beds, succeeds the limestone two miles south of Nix, generally dipping two to three degrees northwest, and continues as the Cretaceous bed rock to the northern limit of Lampasas county. Good exposures of this sandstone occur beneath the Trinity conglomerate near Senterfit along Salt creek and on Antelope creek northwest of Senterfit.

CARBONIFEROUS BASIN AT LAMPASAS.

The town of Lampasas is situated at the lower end of a Paleozoic basin of erosion. This Carboniferous inlier is in the form of a triangle, the three corners of which are on Sulphur creek, at Lampasas, Donaldson creek, at the crossing of the Lampasas-Nix road, and on the south fork of Donaldson creek, nearly due south, at the same road crossing. The line forming these three sides is bordered by a frame of Trinity conglomerate, and is very sinuous. (See accompanying map for special locations upon the line.) Bluffs of thin-bedded shaly limestone and black flaggy bituminous sandy shale, with bands of black obsidian-like flint, occur along Donaldson creek four miles west of Lampasas. At Indian bluff these rocks are admirably exposed in perpendicular walls forty to sixty feet high. Red and white unctuous clay crops out at the base of the bluff. Shale and flinty bands dip nearly southeast. Half a mile below the bluff the bituminous shale dips south 60 degrees east, and three-fourths of a mile below it dips northward.

Along Donaldson creek, one-fourth mile above the large spring, there occurs heavy-bedded encrinital limestone, fissured and jointed, dipping nearly east. Open fissures extend nearly north and south, from which springs issue. There occurs along the hillsides north and west of Lampasas a very hard conglomerate, composed of pebbles of red, mottled red and white, light and dark blue crystaline limestone or marble, and light blue to white flints, in a very hard cement composed of fine fragments of the same material. This conglomerate is apparently without bedding planes. It is believed to be pre-Cretaceous, for the reason that it underlies and is harder than the known Trinity conglomerate here, and to all appearance is composed of pre-Carboniferous materials. Satisfactory connection could not be found between it and the known Carboniferous rocks.

Upon the north and northeast side of Donaldson creek valley the Trinity conglomerate rests in unconformability upon these limestones, sandstones and shales of the Carboniferous and upon the hard conglomerates.

Carboniferous limestones occupy the western and southern portions of the area, and rise to a much higher elevation beneath the Trinity conglomerate than do the Paleozoic rocks upon the north and northeast sides.

TOPOGRAPHY OF THE PALEOZOIC FLOOR WEST OF LAMPASAS.

Erosion followed close upon the edge of the Trinity sand, obliterating the topography that existed, as the Paleozoic floor was covered by Cretaceous sediment. A fair idea of the then existing surface features can be obtained now by following closely along the Trinity border, examining the structure and character of materials entering into its geology, and making a profile of its contacts with the Paleozoic rocks.

The Trinity, along the main Cretaceous border, which extends across Burnet and Lampasas counties, and in the denuded area at Lampasas, furnishes an exceedingly interesting and instructive study.

As has been said for the main border across Burnet county, the Trinity conglomerates and sand rest upon an uneven base, rising rapidly in elevation, from the Colorado river at the Travis-Burnet county line to the northern line of Burnet county, thinning in their course from heavy beds of conglomerate to thin beds of local sub-angular pebbles and bowlders. At the same time beds of limestone, that rest high above the Trinity at the southern border of the county, approach the base of the Cretaceous toward the northern line. The Trinity bed increases in volume again as we go northward from the Lampasas and Burnet county line.

We have seen that the Trinity conglomerate occurs in thick beds around the north and northeast borders of the denuded area at Lampasas, and that its basal contact rises on the south side, while its beds decreased rapidly in that direction. The character of the conglomerate around the perimeter of Carboniferous area at Lampasas has a very local aspect. The basal beds are almost without structure, and the hard sub-angular limestone and flint pebbles and the bowlders composing them can, in a great measure, be identified, as to their age and origin, by the parent rock in the vicinity. The large and small bowlders and pebbles occur together without much order of separation, cemented in a moderately hard lime matrix.

These gravel and bowlder deposits are clearly of beach formation, and were laid down against a Paleozoic ridge which extended from the "Central Mineral Region" in a general east-northeast direction from northern Burnet county. The town of Lampasas is upon the northern and the town of Burnet upon the southern side of this geanticlinal ridge.

HYDROGRAPHY.

The whole of this region belongs to the hydrographic systems of the Colorado and Brazos rivers.

COLORADO-BRAZOS WATER-SHED.—A narrow sinuous plateau crosses the Lampasas county line very near the southwest corner of Hamilton county, and bears toward the southeast one mile east of Montvale and one and one-half miles east of Nix. The Nix-Burnet public road crosses the county line upon the plateau. Naruna and Dobyville, in Burnet county, are upon it, and it passes about two miles east of the town of Burnet. From near Burnet the divide bears nearly due southeast into Travis county, two miles south of its northwest corner. The north line of Travis county marks the summit of the divide across the northern border of the county.

This plateau extends sub-parallel to, and on an average of about

twenty miles from, the Colorado river. Many gaps have been eroded in it by the tributaries of the Colorado on the one side and of the Lampasas and San Gabriel on the other. As soon as the beds of the Fredericksburg division have been removed from the summit of the plateau it becomes a sharp ridge.

COLORADO RIVER DRAINAGE.—From the water-shed east of the Colorado the drainage bears directly toward the river. In Lampasas are Antelope, Salt and Lynch creeks, and in Burnet are Deer, Beaver, Morgan, Clear, Spring, Hamilton, Hairston, Sycamore and Hickory creeks, which rise in the Cretaceous border and flow into the Colorado almost at right angles with the general direction of the river. All of these creeks exhibit typical illustrations of headwater erosion in the Cretaceous. Each one has carved out a small embayment in the Cretaceous border by source erosion alone, for it is rarely more than one mile from the extreme source of the different branches of the creeks to the base of the Cretaceous rocks.

The fall of the tributary streams of the Colorado river west of the water-shed is very much greater per mile than that of the tributaries of the Brazos on the east side. Hence the tendency is for the Colorado drainage to steal that of the Brazos as the border is moved eastward by the deeper headwater erosion of its tributary streams.

BRAZOS RIVER DRAINAGE.—East of the water-shed plateau noted above, the remainder of Lampasas and Burnet counties and the whole of Williamson county belongs to the hydrographic basin of the Brazos river and is drained by the Lampasas and San Gabriel rivers and their tributaries.

LAMPASAS RIVER DRAINAGE.—Beginning in the northwest corner of Lampasas county, the Lampasas river flows from Hamilton county across Lampasas, nearly parallel to the county line, into and across the northeast corner of Burnet, and into Bell county where it joins the Leon, forming Little river. There are many important tributaries to the Lampasas upon the west side of its hydrographic basin. These are Bennett, Sims, School, Big Lucy, Sulphur, with its branches (Donaldson and Burleson), and Mesquite creeks with their various branches and smaller feeders. All of these bear nearly east, except Big Lucy creek, which flows southeast, and Mesquite, which flows northeast. These creeks are fed by many perennial and periodical springs which have their sources of supply in the alternating arenaceous strata of the Glen Rose beds. In the case of Sulphur creek, the abundant water has its source in the magnificent sulphur springs at Lampasas, which issues from fissures in Paleozoic rocks. The character and occurrence of these springs at Lampasas is in no way connected with the artesian water supply of this region. The source of their waters is unknown, and is probably beyond the reach of well boring. The east side of the hydrographic basin of Lampasas river in Lampasas county is very small—on an aver-

age less than six miles wide, and the tributaries are mere branches. With the exception of White creek, in the northern portion, none are of sufficient importance to have names.

The Lampasas and Leon river water-shed is exactly similar in character to that of the Colorado and Brazos rivers, and extends parallel to it practically along the Lampasas and Coryell county line. It is capped by similar beds of rocks, namely: the Comanche Peak and Caprina beds, which have been removed from above the Lampasas river basin by erosion. As is the case with the Colorado river, the Lampasas flows closely upon the east side of its hydrographic basin. Its tributaries also upon the east side have very precipitous inclines. The reason for this is very evident: The river runs nearly south; the rocks dip east-southeast; the general dip of the country is toward or with the dip of the rocks; and erosion is greatest against the edge of the strata and along the line of the dip.

The south fork of Donaldson creek, Mesquite creek, Rocky creek, with its north and south forks, and Mill creek, which belongs to the Lampasas drainage, compose the hydrography of northeastern Burnet county. These creeks all flow toward the northeast. Rocky creek is the only one wholly within the limits of Burnet county.

The economic importance of the Lampasas river valley to Lampasas and Burnet counties, extending as it does the whole length of the former, is almost beyond estimate as an artesian basin. (See Artesian Water.)

SAN GABRIEL RIVER DRAINAGE.—The North Fork of the San Gabriel, with its complements, Russell Fork and Bear creek, and South Fork, with its unnamed tributaries, rise in the Colorado-Brazos divide and flow east-southeast into Williamson county, draining about one-fourth of Burnet county.

The whole of Williamson county belongs to the San Gabriel drainage, with the exception of Salado creek, in the northwest, which is tributary to the Lampasas river, and Donahoe creek, in the northeast, which flows into Little river. Brushy creek, which flows into San Gabriel river in Milam county, drains the southern portion, while the main San Gabriel, with its two branches, the North and South Forks, drains the central and northern portion. The general bearing of the streams within the county is nearly east.

Salado creek rises very near the northwest corner of Williamson, and flows southeast nearly ten miles, then east, and then northeast into Bell county about twelve miles east of the northwest corner. Donahoe creek rises in Bell, near the center of the south side, and flows into Williamson county three miles east of Bartlett.

Williamson and Opossum creeks, which rise at Corn Hill, and two miles southeast of Corn Hill respectively, flow southeast, joining their waters two miles southwest of Granger. Williamson creek continues

eastward and joins the San Gabriel about five miles west of the Williamson-Milam county line.

Berry's creek begins in the edge of Burnet county, four miles southwest of the junction of the lines of Burnet, Bell and Williamson counties, and flows southeast through a narrow valley and joins the San Gabriel river four miles below Georgetown.

North Fork of San Gabriel enters Williamson county four miles northwest of Gabriel Mills and flows east-southeast to Georgetown, and then nearly east to Circleville, from which point it bears east-northeast to the Milam county line. This stream rises high upon the beds of the Fredericksburg and flows down upon the rocks through a wide sloping valley to Gabriel Mills, where it begins to rise or rather pass upon beds of higher rocks. The valley continues wide with gently sloping sides. Twelve miles above Georgetown heavy beds of limestones and flint approach the river valley and form precipitous and high bluffs. The valley here becomes narrow and level, extending up to the base of the bluff. At Georgetown the Balcones fault has thrown these heavy beds of limestone down below the level of the river valley. Here the topography changes, the river valley becomes wider and the hills rolling.

South Fork of San Gabriel crosses the Burnet-Williamson county line one mile south of the Austin and Northwestern Railway. The valley is not so wide, on an average, as that of the North Fork. The massive limestones and flints approach near the flood basin of the river and form bluffy valley walls. Now the river flows against one side of the valley and forms perpendicular cliffs, then further down it flows against the other side, shifting the river bottom, or valley base, from one side to the other. This prong of the San Gabriel joins with the North Fork at Georgetown.

The various small branches of Brushy creek have their source in the Colorado-Brazos plateau between Bagdad and Breuggerhoff, near the Travis-Williamson county line. The two main prongs, Dry and Running Brushy creeks, join four miles above Round Rock. From Round Rock Brushy creek flows east-southeast until it approaches very near the Travis county line south of Taylor, where it turns to the northeast, passing the east line of Williamson county two miles south of Thorndale. Channel, McNutt, Battleground, Mustang and Turkey are small affluents of Brushy creek on the north side. Lake and Boggy creeks are feeders on the south side.

Springs.—Upon all of the creeks which flow eastward over Cretaceous rocks in Lampasas and Burnet counties, and Williamson county west of Round Rock, Georgetown and Corn Hill, there are many springs flowing during a part or all of the year. Very few of them (except those to be noted below as flowing from fissures) afford abundance of water; but where their waters accumulate, living streams are

formed. During a long drought, however, many of these springs fail, and water even for culinary supply must be sought in wells.

The source of supply of springs of this class is local, and the abundance of supply is governed by the local catchment area and the annual rainfall. For an illustration, take the valley of South Rocky creek in Burnet county, and make a section of the rocks down it from Mesquite creek valley.

Much of the water that flows in Mesquite creek and that falls as rain upon the southern slopes of the valley enters certain underlying porous strata and follows them down until it reaches the surface in the valley of Rocky creek. During the rainy seasons of the year these porous arenaceous beds are filled and act as reservoirs for the spring until they are exhausted by a long drought.

Upon the southeastward sloping valley sides these water-bearing beds may be penetrated by wells, for which they will furnish abundant supplies of water; but upon the valley sides which slope toward the northwest much less, and in some cases, no supply can be expected.

Many beautiful springs, natural artesian wells, gush forth from fissures in the limestone rock along the valleys of the North and South Forks near Georgetown. There is a cluster of beautiful and bold springs issuing from the banks of San Gabriel on Senator Glasscock's property opposite the city waterworks below Georgetown, giving forth many thousand gallons of water per hour.

A large spring bursts forth from the top of the bluff on the east side of North Fork San Gabriel four miles above Georgetown, pouring out four thousand gallons per hour. A cluster of springs breaks out upon the south side of North San Gabriel valley, eight miles above Georgetown, on the property of Mr. Crockett. These springs join their waters at the border of the valley, and by simply directing the flow Mr. Crockett irrigates successfully a beautiful vegetable farm of seventeen acres. The principal spring bursts forth from beneath a bluff of limestone, at Mr. Crockett's house, nearly one hundred feet above the base of the river, and has formed a bluff of tufaceous lime two hundred yards long and twenty feet high, the edge, over which the waters fall, being now nearly three hundred feet from the spring.

An excellent spring issues from an opening in the Balcones fault, in the bed of Brushy creek, on the northeast side of Round Rock. Above Round Rock many others break out from fissures or joints in the rock along the creek for several miles in sufficient volume to cause a continual stream.

At Town's Mill, six miles east of Georgetown, living springs of small volume issue from joints and small faults in the limestone.

A number of springs occur along the south side of San Gabriel river valley from four to eight miles from the Williamson county line.

These springs have their source in the drift which occupies the high land in eastern Williamson county.

Many feet of gravel drift have been deposited upon a floor of impervious marl. Water falling upon the surface as rain finds its way to the base of the drift and issues in springs at the edge of the river valley. Many of these springs have a considerable volume and a perpetual flow.

BOSQUE DIVISION.

c. Paluxy sand.
b. Glen rose (Alterating) limestone.
a. Trinity sand.

TRINITY SAND.

The Trinity occurs along the base of the escarpment at Nix, between Nix and the south line of the county, at the base of Twin Sisters Peaks, between Twin Sisters Peaks and Montvale along the western base of the high plateau; on the branches of Salt creek near the Gulf, Colorado and Santa Fe Railway, and at the base of the escarpment southwest and northwest of Antelope Gap on the head branches of Antelope creek.

A zone of Trinity conglomerates crops out around the perimeter of the Carboniferous area at Lampasas. Extending west from Lampasas, it occurs along the north side of Donaldson creek valley to the Lampasas and Nix road. From the Lampasas-Nix road, it bears nearly south to the south fork of Donaldson creek, whence it takes a northwesterly bearing passing along the south side of the creek valley and crossing Sulphur creek about two miles below the town. From the point of crossing on Sulphur creek it occurs along the hillsides east, north and west of Lampasas.

In the vicinty of Nix the basal beds of the Trinity are composed of a conglomerate of Carboniferous and Silurian limestone, quartz, flint, and other Paleozoic material, cemented in a matrix of arenaceous and argillaceous lime. Small fragments of sand and gravel compose much of the matrix, which is in some cases iron-stained and very hard. The whole mass has a mottled appearance from the variously colored materials composing it. The colors are pink, red, yellow, purple, brown, and several shades of blue. The materials which compose the conglomerate vary much in size, being from fine pebbles to bowlders eight inches in diameter. Their form indicates that they have been subjected to different degrees of abrasion. Some of them are sub-angular fragments, while others are smooth and well rounded; and between these grades there may be seen fragments of rocks showing all varieties of form and smoothness of surface.

There is a general stratification in these basal beds, but the materials which compose them are not well sorted as to size. The immediate impression upon an examination of this heterogeneous conglomerate

is, that there was a commingling on the shores of the sea of materials brought from a distance and local debris. This coarse material gradually becomes less conglomeritic on ascending the beds, giving place to a mass of loosely bedded materials composed of grits, typical "packsand," lime marl, and calcareous sandstone. The whole grades imperceptibly into the more calcareous and marly strata of the Alternating series. The "packsand" varies in texture from a compact, non-indurated, yellowish mass of coarse sand, quartz and chert pebbles, to a more close-grained, stratified, calcareous sandstone, brown to whitish in color. Strata of limy sand occur in thin variable beds.

The whole of the Trinity at Nix will not exceed fifty feet. Twenty to twenty-five feet of the basal portion will include the conglomerate. The "packsand" with associated material is thirty feet thick. The upper half contains the more calcareous sandstone, lime, and marly material.

The parting line between the Trinity and Alternating beds is necessarily an arbitrary one from a stratigraphic point of view, and there is no other means of distinction. Yet in the more limy thin bands within the limits of the sand, near its upper limit, there are casts of gasteropods and small bivalves not distinguishable from casts of like forms in the Alternating series.

GLEN ROSE (ALTERNATING) BEDS.

The sandy beds of the Trinity are succeeded by about eighty feet of true Alternating beds at Nix and in Twin Sisters Peaks. These beds become less arenaceous and more marly and calcareous on going from base to upper limit. The characteristic nature of the Alternating series is well shown. Soft, impure limestone, alternating with layers of marly lime and soft yellow calcareous sandstone, the whole being stratified in thin beds dipping gently and regularly toward the southeast. These are distinguishing characteristics of the series.

The lime marl and sandy strata readily disintegrates and falls into a marly earth, yellow to white in color, while the harder lime layers are slower of disintegration, remaining as slightly projecting benches, breaking into fragments of stone and crumbling lumps as the softer bands fall away from beneath them. The stratification of these beds is very marked and readily perceived on account of the varying hardnesses of the rock. The strata vary in thickness usually from a few inches to an extremely thin laminated band, but in places a more massive stratum of limestone or calcareous sandstone occurs.

The Alternating beds proper are not so thick near the western border at Nix and Twin Sisters Peaks as they are further southeast. In Twin Sisters Peaks, about ninety feet is shown to occur, while at Bachelor Peak, eighteen miles to the southeast, they show a thickness of

over two hundred feet. As the beds develop, there is a general thickening of the individual strata.

FAUNAL SUBDIVISIONS.—A horizon of small *Exogyra* (*Exogyra* sp. ind.) occurs in Twin Sisters Peaks fifty feet beneath the summit of the series. At Bachelor Peak it is one hundred and fifty feet beneath. This is the same bed that occurs on the Colorado section, Bosque section, and in the Weatherford section, as described in the report on the Bosque division.

An extremely fossiliferous horizon occurs two hundred feet below the upper edge of the Alternating beds in Bachelor Peak section, as is well shown on Mesquite creek northeast of the Peak. Its characters are well presented wherever observed. The bed contains well preserved casts of *Cardium mediale.*

The bed usually forms bluffs along the creeks, as may be seen at the mouth of Pecan branch, northeast of Bachelor Peak. These bluffs are composed of beautifully stratified, very arenaceous limestone, bluish white to gray, which alternates with marly and arenaceous strata similarly stratified. The marl is composed of soft laminated limy marl, bluish to gray in color. It is crumbling, and weathers out easily, causing the harder limestone layers to project in ledges along the bluffs and "brakes" of the creeks. This horizon is also well exposed on North Rocky and South Rocky creeks, both above and below the crossing of the Lampasas and Georgetown road.

A Caprotina horizon occurs just below the Cardium bed in a band of hard arenaceous limestone ten feet thick. The rock weathers with a peculiar rough surface.

Above the Cardium bed about fifty feet, there is a massive bed of light yellow magnesian (?) limestone in strata about three feet thick.

CELESTITE BED.—In a marly bed, below the heavy limestones, pockets of celestite were found in the bluffs along Rocky and South Rocky creeks. The celestite is very abundant, occurring in very large nodules or inclusions. The same horizon occurs on South Rocky creek near the Lampasas-Georgetown road, and in a high bluff on the creek three miles below the same road crossing. Also abundantly on Donaldson creek due east of Nix. Beautiful blue crystals are found in large nodules in the yellow arenaceous limestone, and they also occur with calcite nodules around the face of the hills north of Nix.

OCCURRENCE.—The rocks of this bed are exposed along the valley of the Lampasas river through Lampasas and Burnet counties as well as along every creek valley tributary to this river. The confluents to these tributary creeks have also cut valleys for themselves into the marl and lime rocks of the Alternating beds, except near the sources of the head streams that rise upon the plateau divides between the Lampasas and Colorado rivers and between the Lampasas and Leon rivers along the east line of Lampasas county.

The long arms of high land which extend southeastward between the principal creeks, viz: Bennett, Sims, Big Lucy, Donaldson, Mesquite, North Rocky, South Rocky and Miller creeks, are capped by rocks of the Fredericksburg division. Hence the wide or narrow valleys of these creeks have been chiseled out by agents of erosion after these agents have cut through the chalky limestones of the Fredericksburg.

Alternating beds are concealed by higher rocks along the water-shed divide, running nearly east and west north of Strickling, Burnet county, and Florence, Williamson county, between the hydrographic basin of Lampasas and San Gabriel rivers. North Fork of San Gabriel river, with its main tributaries, Russell Fork and Bear creek run through valleys of Alternating limestone for a great portion of its course in Burnet county. Its exposure of these rocks is narrow, however, and contracts continually as it passes southeast in Williamson county, until it is carried beneath the surface near Baker's School House, twelve miles above Georgetown.

These rocks outcrop along the escarpment face on the western border of the Colorado-Brazos water-shed, as has already been outlined in the occurrence of the Trinity. They form the upper half of the declivity beneath the capping of the Fredericksburg limestone.

PALUXY SAND.

The Paluxy sand has a very feeble representative in this section. Upon the western border near Nix it is not present in a definable bed. Arenaceous limestone, or a very calcareous sandstone, occurs in its stead at the summit of the Alternating series.

An argillaceous calcareous sand, fifteen feet thick, occurs in the base of Bachelor's Peak, Burnet county. It is between the Alternating and Texana beds, and is considered to be a representative of the culminating portion of the Paluxy sand bed in this region. This sand crops out around the head of North Rocky creek, south and east of Bachelor Peak. Where it occupies a level surface of much extent, "skirts" and clumps of timber appear upon it, and it is a source of many small springs. Wells sunk into it are abundantly supplied with water.

FREDERICKSBURG DIVISION.

i. Kiamitia clay.
h. Austin marble.
g. Flag limestone.
f. Caprina limestone.
e. Comanche Peak limestone.
d. Texana limestone.

TEXANA LIMESTONE.

This subdivison is limited by the occurrence of the *Exogyra texana* beneath the Comanche Peak limestone. At the top of the Paluxy

sand there occur thin bands of limestone which contain great numbers of this *Exogyra*. It occurs at various localities in the midst of the bed and at the summit where the rocks grade into the Comanche Peak limestone, without a lithologic change.

OCCURRENCE OF EXPOSURES.—The Texana bed occurs on the sloping hillsides beneath the precipitous and bluffy beds of Comanche Peak and Caprina limestone, along the sides of the escarpment of the water-shed plateaus east, northeast and north of Nix, in Twin Sisters Peaks, in Cedar Top Peak, and the line of knobs northwest of it south of the Gulf, Colorado and Santa Fe Railway, also on the tops of the hill-sides north of Lampasas.

Along the section line between the hills east of Nix and Bachelor Peak the Texana bed has been removed by the erosion of Donaldson and Mesquite creeks. It crops out at the base of Bachelor Peak, and forms the surface of the high land east and west of the Peak. It also caps the divide between North Rocky and South Rocky creeks north of Sunny Lane. It underlies and forms the rich black lands upon the water-shed divide between Rocky creek and San Gabriel river north of Mahomet and Strickling.

Pilot and Black Bald knobs stand upon a plain formed by the Texana bed. From Pilot Knob southeast it crops out along the sides of San Gabriel river valley, approaching nearer and nearer the river until its upper edge reaches the river bed nearly three miles above Georgetown. The exposure from Baker's School House, twelve miles above Georgetown, to the point where it disappears beneath the river's base, is confined to the immediate flood basin of the river along its banks and beneath the bluffs at the edge of the valley. It occurs in the hills on each side of Bear creek and between Bear creek and Russell Fork of San Gabriel river.

CHARACTER AND THICKNESS.—The Texana bed has not as great a development in Twin Sisters Peaks and in its occurrence east and north of Nix and other points near the western border, as it has in Bachelor Peak and Pilot Knob. In Twin Sisters Peak it is nearly seventy feet, while in Bachelor Peak it is nearly eighty feet thick.

Beginning at the base of the bed, and continuing upward for nearly forty feet, there are narrow bands of fossiliferous limestone which contain principally *Exogyra texana*, *Gryphæa pitcheri* and *Trigonia crenulata*, alternating with thick layers of yellow argillaceous lime marl. Then there is fifteen feet of massive shell limestone composed almost wholly of *Exogyra texana*, *Gryphæa pitcheri* and *Ammonites peruvianus*, or *A. acuto-carinatus*.

On the disintegration of this rock the fossils completely cover the surface, there being not more than sufficient lime to cause the fossils to adhere. Above this, to the top of the bed, there is a zone of chalky stratified limestone, grading in color from white to light yellow. This

contains numbers of small *Gryphæa pitcheri*, largest *Exogyra texana*, *Cyprimeria crassa*, *Cardium hillanum*, *Toxaster texanus*. *Diadema texanum*, and rarely *Ammonites pedernalis*. The most abundant occurrence of the *Toxaster texanus* is very near the upper limit of the base. The *Exogyra texana* attains its greatest size in the chalky limestone at the upper limit of the bed.

COMANCHE PEAK LIMESTONE.

The basal beds of this subdivision are a continuation of the chalky strata of the Texana bed, and as has already been pointed out, the contact of the two beds is marked by the disappearance of *Exogyra texana* fossils. These rocks rise above the Texana bed in a series of chalky layers, which increase in massiveness upward until they are finally terminated by a massive indurated and persistent band of chalky limestone. This culminating bed is about twenty feet thick, composed of layers three to six feet thick.

Distinct faunal horizons were not observed in the Comanche Peak limestone. It contains *Cardium hillanum*, *Toxaster texanus*, *Turritella seriatim-granulata*, *Diadema* sp.(?), *Cyprimeria crassa*.

The rock of this bed weathers into a mass of white conchoidal fragments at the surface; and where it occupies a sloping hillside, as in Twin Sisters Peaks, Cedar Top Peak and Bachelor Peak, it is barren of vegetation except an occasional stunted liveoak tree or scattering sedge tufts. Where it occupies a level plateau, and erosion is very slight, a rich black residual soil is formed. A typical occurrence under this condition is upon a part of the high divide north of San Gabriel river, in Burnet county, also upon the "flat" east of Pilot Knob, Burnet county.

EXPOSURES.—The section crosses this rock beneath the capping bluff in the hills east of Nix, in Bachelor Peak, where it forms the cone of the peak, and in the body of Pilot Knob below the cap rock. East of Pilot Knob it is the surface rock for one mile. Here the section descends upon the Texana bed and continues for about two miles, where it ascends upon Comanche Peak limestones, and so continues for about five miles. At this point it dips beneath Caprina limestones, and is not seen again upon the section toward the east.

It forms the bluffs in part along the side of San Gabriel river valley from Baker's School House to the edge of Georgetown west of the great Balcones fault.

CAPRINA LIMESTONE.

STRATIGRAPHIC CHARACTER.—(1). The massive layers of the Comanche Peak bed are succeeded by thick bands of limestone, varying but little from them in general appearance, except that some of them weather in pores until they are a homogeneous mass, or the "bored limestone," as it is known locally. Upon a close examination prints

and casts of *Rudistes*, *Caprina crassifibra* and *Caprina* sp. ind., may be seen in the limestone. This limestone is the basal zone of the magnificent *Rudistes* and *Chamidæ* fauna that occur in the Caprina limestone subdivision. This horizon has a thickness of nearly twenty feet.

(2). Succeeding these heavy bands of limestone are about thirty-five feet of limestone strata, siliceous, hard, from three to five feet thick. Where this rock is freshly fractured, it has the appearance of a hard crystalline limestone; but upon weathering, fine clear grains of quartz sand appear on the surface. Intermediate between some of these layers of limestone, and placed in collective strata, there are thin bands of fossiliferous, indurated, flinty limestone, resembling quartzite. These flinty layers contain many shell fragments, minute gasteropods and oolitic grains. Upon weathering these fossils stand in relief on the face of the flagstone.

(3). Third in the order of succession there are heavy strata of dimension limestone having a thickness of about twenty-five feet. At the base and at the top of this horizon is a disconnected band of large oval agatic flints, white to light blue in color. Some of these flints contain cavities lined with beautiful limpid quartz crystals. Some of the limestone layers are quite siliceous, especially those immediately surrounding the flints.

(4). A belt of limestone, nearly twenty-five feet thick, overlies the agatic flint zone. In this there is very much brown flint in nodular bands, which are not continuous. They may be observed in one locality in the form of a solid belt of flint-like flagstone, while in another place they are either absent or occur as nodules. A horizon of *Caprotina texana* (?) occurs in the upper portion of this flinty belt. They may be seen upon the surface inclosed in the flint nodules.

(5). Chalky limestone in thick massive strata, fifteen feet thick. In the excellent exposures of the Caprina bed in the bluffs of Barton creek, south of Austin, this limestone belt contains layers of ashen blue crumbling limestone which are crowded with most beautiful translucent calcified fossils of Caprotina, corals, gasteropods and bivalves. Their preservation is unique, showing every marking, and in beauty they equal living species. These fossils were not seen in the section on Brushy creek near Round Rock. On Barton creek a band of black flint nodules, which is apparently absent here, occurs immediately above this fossiliferous horizon.

(6). Dull blue limestone, three feet thick, follows upon the massive limestone. In this there are many *Caprina crassifibra* and *Caprotina* sp. ind.

(7). The next succeeding strata of light blue and white limestone contains great numbers of *Hippurites flabellifera*, Dumble. This fossil is so abundant along the banks and bluffs of Barton creek that it is not

possible to collect a fragment of one fossil from the rock without the destruction of others.

In the section on Brushy creek black flints occur twenty-seven feet below the summit of the Caprina subdivision. Where these appear the rock is chalky and in massive beds. The flints occur in the massive beds, and between the strata, as broken bands and lens-like nodules. These black flints, from their lower to their upper limits, have a range of twenty-three feet.

As far as known there is about thirteen feet of barren limestone above the *Hippurites flabellifera* zone. This limestone includes the base of the black flint belt.

(8). There are seven feet of indurated, hard, thick-bedded limestone, which contains *Caprotina* fossils. This much resembles the Austin marble, which occurs near the summit of the Fredericksburg division.

(9). There is an eight-foot zone of yellow chalky limestone which extends nearly to the upper limit of the Caprina bed. In this chalky limestone there occur *Exogyra texana* fossils, which have not been seen since their occurrence, as noted before, at the base of the Fredericksburg division, nearly two hundred and fifty feet beneath this horizon, and they are not known to exist in higher beds.

As the rocks of this bed are ascended from the medial portion, the limestone is observed to become more nearly pure and more chalky in texture, until very near the summit strata are found which are almost pure lime, friable and of chalky whiteness. A specimen of a stratum of limestone, two to four feet thick, just above the final occurrence of the black flint, showed upon analysis 98 per cent of carbonate of lime. These chalky layers at the top of the Caprina bed grade gradually up into the thinner dimension layers of the flag limestone. The total thickness of the Caprina bed is, by the closest estimate, one hundred and sixty feet.

OCCURRENCE.—Along the immediate line of section the Caprina bed is exposed from the depot at Georgetown to six miles northwest of the town, where it is abruptly cut off and concealed by the Balcones fault. The basal portion of the bed only is exposed here, including the agatic flint zone. It forms the cap rock of Pilot Knob and of the high divide east and north of Nix.

The high land between the North and South Forks of San Gabriel river is occupied by a part of the Caprina bed. It does not occur east of a line drawn from Georgetown to Round Rock, which is the line of the Balcones fault. From this line westward it forms the surface country rock to the edge of the hydrographic basin of the Colorado river, except for a short distance along the immediate valleys of Dry and Running Brushy creeks above their junction.

Brushy creek, with its banks and bluffs, presents from base to top a

most excellent section of the Caprina bed. At this locality the Balcones fault intersects Brushy creek east of the occurrence of the limestone (Caprina), hence the strata are not affected by it.

FLAG LIMESTONE.*

This limestone succeeds the last or final chalky horizon of the Caprina bed which contains the bands of black flint nodules. In Brushy creek, at Round Rock, where a representative section is exposed, the bed begins at the base with a ledge of siliceous lime two inches thick. This is succeeded by about one inch of oolitic semi-crystalline limestone. Above this ledge there occur flaggy layers, some of which are inclined to be chalky, while others are crystalline and finely oolitic. From the middle to the top of the bed the rocks are more truly flaggy in nature. There are indications, almost throughout the bed, of shallow water action in the oolitic lime and in the wavy lines upon the laminated layers. Ripple marks occur upon some of the flagstones, though they are nearly pure lime. The nature of the flagstones in this respect point to a history of shallow water at sea beyond the reach of near-shore deposits. They are practically barren of fossils, small fragments of shells only having been seen in them. Their aggregate thickness at this locality and on the Colorado river, west of Austin, is nearly ten feet.

The rocks of this bed are involved in the disturbance incident to the great fault along the occurrence of their outcrops. Hence in but few localities has it been possible to study them satisfactorily. In the valley of the San Gabriel they have been totally concealed by the downthrow of the fault.

AUSTIN MARBLE.†

This bed as it occurs on Brushy creek, at Round Rock, and at other

*The flag limestone has been given equal prominence with the Fort Worth and Arietina beds of the Washita division, and with the Caprina and Comanche Peak beds of the Fredericksburg division, (A Brief Description of the Cretaceous Rocks of Texas and Their Economic Uses, R. T. Hill, in the First Annual Report of the Geological Survey of Texas, page 127), a prominence which it does not rightfully deserve. It is local in its occurrence, and is not more extensive or prominent than many horizons of like nature within the limits of the Caprina subdivision. It is tentatively considered in its relation here given, because of the prominence heretofore given it, and because it has not been possible up to the present time to give it thorough study.

† The name "Austin marble" is unsatisfactory and misleading. In only one locality, where it is involved in the disturbance of the Balcones fault, does it take, in any way, the property of marble. In the quarries west of Austin, and at the south base of Mount Bonnell, this rock is a compact cream colored or yellowish marble, where it was named "Caprotina limestone, or Austin marble." See Bulletin No. 4, Geological Survey of Texas, R. T. Hill. The term "Caprotina limestone" is altogether objectionable, as there are several other beds of Caprotina limestone below this in the Fredericksburg and Bosque divisions.

points along the line of the great fault, is a white, nearly pure limestone, composed almost wholly of *Rudistes*, *Caprina*, and *Caprotina* fossils. It is the culminating bed for the *Caprina* and *Caprotina* forms occurring in the beds below. Above this zone of their greatest abundance no forms of the *Chamidæ* have been observed in the Lower Cretaceous series in this region.

The limits of the Austin marble are clearly defined by the occurrence of the fossils contained in it and by the character of the rock. Its chalky whiteness, as it occurs at Round Rock, is a contrast to the dull blue flagstones below and to the Kiamitia and Fort Worth limestones above. Yet it is neither a chalk nor a very hard limestone.

OCCURRENCE.—The Austin marble diminishes in thickness to the northward from the Colorado river, as does the Caprina bed below, and is not known to occur north of the Brazos river. The whole bed, which is about six feet thick, occurs in the bed and banks of Brushy creek at Round Rock. Its outcrop here is a few hundred yards west of the Balcones fault. As it is traced northward it soon approaches and is concealed by having been thrown beneath the surface by the fault. At Georgetown the Fort Worth limestone, which overlies the Austin limestone, comes in contact at the fault with the Caprina bed.

KIAMITIA CLAY.

In our section the Kiamitia bed is known to occur only at Round Rock. It is concealed by the downthrow of the fault in the valley of the San Gabriel river. Its rocks have not been observed between Brushy creek, in Williamson county, and Trinity river, west of Fort Worth. The clay, with included *Gryphæa* bands, crops out along the valley of Red River northwest of Gainesville. Still further down the valley there are extensive outcrops in the north edge of Grayson county. With still greater development the beds appear in the Indian Territory at Goodland.

In the locality of the section there is no clear line of demarcation between the rocks of the Kiamitia and Fort Worth beds. The Kiamitia bed begins at the base in earthy, blue, marly, rather hard limestone, and grades up without perceptible change about six feet into the Fort Worth beds. The border line is drawn at the upper limit of the occurrence of the *Gryphæa forniculata* phase of the *Gryphæa* types, and at the base of the *Exogyra columbella* horizon, which occurs at the border between the two beds, north of Denison, in the banks of Duck creek, at which place they may be clearly defined both lithologically and paleontologically. The surface character of the rock of this bed here, and its effect on the soil or surface conditions, is not perceptibly different from the influence of the body of the Fort Worth limestone.

The fauna of the Kiamitia bed, so far as it is known, are characteristically Fredericksburg forms. The phase of the *Gryphæa* (*G. forni-*

culata) occurring in this bed has a range in form from the characteristic types to a form very closely related to the *G. tucumcari*. Between the *Gryphæa pitcheri* of the Texana bed and the *G. washita* of the Fort Worth limestone, that of the Kiamitia is more nearly allied to the former.

The *Ammonites acuto-carinatus*, which occurs so abundantly in the Kiamitia bed, is the characteristic ammonite of the Texana bed at the base of the Fredericksburg division. It occurs in greater numbers near the center of the Texana bed than in the Kiamitia clay.

WASHITA DIVISION.

l. Vola limestone.
k. Arietina clay.
j. Fort Worth limestone.

FORT WORTH LIMESTONE.

In general character the Fort Worth limestone is a stratified and marly shell limestone, dull blue and earthy colored. It occurs in indurated bands from four to five feet thick down to four or five inches. The marly layers alternate with the hard lime bands in thickness of six inches and less to thin laminæ. The gradation from marly hard lime bands is very gradual so that clearly defined lines cannot be drawn between them. Upon weathering in bluffs the hard ledges form sloping or oval bordered shelves, the center of the marly band being recessed furtherest into the bluff.

In portions of this bed fossil shells form the mass of the rock. Shells of *Ostrea*, *Pecten*, and *Terebratula* or casts of *Echinoids*, *Ammonites*, and *Nautili*, either in complete forms or fragments, occur in every band from the base to the top. In some instances, as in the *Gryphæa* horizon near the upper portion of the bed, these shells are so numerous as to cover completely the surface of the degraded rock.

FAUNAL HORIZONS.—*Exogyra columbella* was not known to occur in the Texas Cretaceous rock, until late investigation by the Survey in North Texas and on Brushy creek in Williamson county, proved that a horizon of this fossil occurs at the base of the Fort Worth limestone, associated with numerous individuals of *Terebratula wacoensis* and *Gryphæa washita*.

In the banks of Duck creek, one-fourth mile below the Missouri, Kansas and Texas Railway, in Grayson county, it ranges through about four feet of indurated and marly limestone, beginning immediately above the final occurrence of *G. forniculata* and Kiamitia clay.

The fossil is rarely an inch in length, and is unique in form and in beauty of marking. In its occurrence in Brushy creek, at Round Rock, it bears the same relations to the Kiamitia and Fort Worth beds as it does at Duck creek locality.

Through a range of about fifty feet above the *Exogyra columbella* horizon there occurs a very rich *Ammonite* fauna. *Ammonites* and *Nautili* of different species abound in great numbers in a thick-bedded hard limestone with narrow partitions of marly lime. Above the Ammonites zone, as may be observed in the bluffs of the San Gabriel river, one-half mile below the water power station at Georgetown, there is a narrow horizon of limestone a few feet in thickness containing echinoids. Above the echinoid horizon there is a zone of marly and thin-bedded limestone, which contains numberless individuals of *Gryphæa washita*, many *Pecten texanus*, and also a few *Ostrea carinata*, occasional echinoids, *Exogyra walkeri*, etc.

Many *Gryphæa washita* may be found both above and below this horizon, but they occur here in their greatest abundance. Ledges of rock several inches in thickness are composed almost wholly of these fossil shells.

As the upper portion of the bed is approached, numerous *Exogyra walkeri* and *Ostrea carinata* appear. The echinoids and *Nautili* occurring in the horizons of the lower portions of the bed are quite numerous here also. An occasional *Ostrea subovata* is present in this horizon. Within four to six feet of the summit of the Fort Worth limestone great numbers of *Terebratula wacoensis* occur, with occasional *Ostrea carinata*, *Nautilus* and *Pecten*. The *Terebratula* continues in profusion even through the transition argillaceous lime between the Fort Worth limestone and Arietina clay. At the upper edge of this transition band of lime and clay *Terebratula wacoensis* and *Exogyra arietina* fossils are intermingled in the rock.

The horizons or zones indicated above for the occurrence of each characteristic Washita or Fort Worth fossil form is not the limit of its culmination or locality of its greatest abundance. The *Terebratula wacoensis*, for instance, ranges from the base of the *Exogyra columbella* zone upward to the base of the *Exogyra arietina* clay.

LOCALITY.—On the San Gabriel river, opposite Georgetown, a few feet of the basal portion of the Fort Worth limestone is concealed by the downthrow of the Balcones fault. Below the fault these rocks have many beautiful exposures for two and one-half miles below the river.

At Georgetown, for nearly one-half mile along the river banks, and at the base of the high bluffs one-half mile below the water power station, the lower portion of the bed, including the Ammonite zone, is exposed. The high bluff designated above exhibited the *Gryphæa* horizon for many hundred feet along the north side of the river. Large bowlders and fragments of the rock lie in heaps at the base of the bluffs displaying the rich fossil fauna.

Extensive exposures of the upper division of the bed occur along the river, from two to three miles below Georgetown, at the base of the

high bluff of Arietina clay and Vola limestone. Portions of the bed may be seen along Berry's creek, from two to three miles above its mouth.

The Balcones fault cuts the Fort Worth limestone on Brushy creek, at Round Rock, and conceals nearly one hundred feet of its strata by downthrow on the east side of its fault line. The lower portion of the bed, however, including the *Exogyra columbella* and a part of the Ammonites zone, is well exposed along the banks of the creek. Portions of the bed crop out in a narrow belt between Round Rock and Georgetown.

ARIETINA CLAY.

The Arietina clay is the most peculiar geologic formation in the whole of the Lower Cretaceous. The occurrence of a continuous bed of clay, of almost unvarying thickness, from the Brazos river to the Rio Grande, a distance of nearly four hundred miles, is a feature worthy of special note. The characteristic and unique *Exogyra arietina* of this bed occurs in the greatest abundance wherever the bed is found.

The change is abrupt and complete, lithologically, from the *Terebratula* horizon of the Fort Worth limestone below to the Arietina clay, and the line of demarcation between the clay and Vola limestone above is equally as abrupt and sharply defined. The limestone of the *Terebratula* horizon is compact, while the clay is friable in structure and disintegrates readily when exposed.

The clay is blue in color, from particles of iron pyrites disseminated through it. When the clay has disintegrated these particles of pyrites decompose, giving it by the oxidation of the iron, various shades of coloring from blue to deep yellow. At the same time the sulphur component of the pyrites combines with the sulphuric acid and lime constitutents of the clay and forms gypsum. Crystals of selenite from this source occur in abundance on the surface and disseminated in the clay and in joints and small fissures at a certain stage in the decomposition from clay to soil.

Laminations show in the clay wherever fresh weathered surfaces are exposed. This is especially apparent in the upper portion of the clay, where also *Exogyra arietina* fossils form flaggy stones, the fossils being cemented together by ferruginous lime. Thin flags of laminated arenaceous and argillaceous lime occur also near the upper edge of the Arietina clays.

FAUNAL SUBDIVISIONS.—*Exogyra arietina* is present in many or few numbers throughout the clay, but its zone of prevalence is near the center of the bed. Through a range of nearly fifteen feet from the center of the bed upward, this beautiful fossil is found in countless numbers in the clay, and forms masses of rock. As the clay disintegrates, the fossil remains as a mantle covering the surface. With the

Exogyra arietina in this central zone, there are *Ostrea* sp. ind. and *Gryphæa pitcheri*, Morton, var. *navia*, Hall, and *Pecten texanus*(?). *Terebratula wacoensis*, as above cited, occurs at the base, associated with *Exogyra arietina*. Both are found from four to six inches above the base of the bed, which is considered to begin with the lowest *Exogyra arietina* fossil.

As the upper border of the Arietina clay is approached, many *Gryphæa pitcheri* var. *navia*, may be seen weathering out of the clay with *Pecten quadricostatus* and *Ostrea* sp. ind. The *Gryphæa* increases in numbers upward from its lowest occurrence to the parting between the clay and Vola limestone. These fossils form a coating on the base of the limestone, and occur in great numbers in the edge of the clay.

LOCAL DISTRIBUTION.—High bluffs of Arietina clay form the south bank of San Gabriel river, two or three miles below Georgetown. Its occurrence in the base of the river is concealed by the lake formed by the dam of Town's mill.

The clays crop out in the escarpment slopes two miles east, southeast and south of Georgetown. It approaches the Georgetown and Round Rock road three miles south of Georgetown, and continues in a narrow belt of exposure nearly due south to Brushy creek at Round Rock. At this point it is nearly concealed by the downthrow of the Balcones fault, only about ten feet of the upper edge of the clay remaining at the surface.

VOLA LIMESTONE.

The Vola limestone is the uppermost subdivision or bed of the Washita division, and is the final bed of the Lower Cretaceous throughout Central and Southern Texas.

North of Bosque river mid-Cretaceous erosion and overlap of the rocks of the Red River division has removed or concealed the Vola limestone. South of the Bosque river it is the floor for the lowest member of the Upper Cretaceous series.

In the western limits of Austin this bed is nearly eighty feet thick. From this place it decreases in thickness northward at the rate of about two feet per mile. At Round Rock it is nearly twenty feet thick, and on the San Gabriel it has diminished to less than ten feet. When fractured freshly the surface presents a mottled face. The rock, a gray or light blue limestone, is seen to be filled with minute red specks and pink splotches. Under the microscope some of these unoxidized particles present a greenish tinge, indicating probably that they are particles of volcanic ash, thrown down during the deposition of the limestone.* A thorough microscopic study has not been made of the rocks.

This limestone is stratified in massive layers two to six feet thick.

* See Bulletin No. 4, Geological Survey of Texas, page 24.

It contains an abundant fauna of *Pecten* (*Vola*) *roemeri*, Hill, a large *Nerinea* sp. ind. and bivalves undetermined.

The *Gryphæa pitcheri* var. *navia*, which occurs at the base of the limestone and in the clay below, passes upward into the limestone as far as one foot. This fossil forms the basal band of limestone. Above this, however, it is not seen again.

SURFACE EXPOSURES.—A low bench of this limestone caps the high bluff two to three miles below Georgetown on the south side of the San Gabriel river, and forms the crest of the escarpment that extends from the west end of this bluff around the valley two to three miles east and southeast, and three miles south of Georgetown. From the road three miles south of Georgetown it continues south, capping the low escarpment to Brushy creek opposite Round Rock.

The presence of the Vola limestone has caused the bluff and escarpment above noticed. The Arietina clay "slacks," and falls a ready prey to agents of erosion, but it is held in check and protected by the overlying bed of Vola limestone. As the clay gives way beneath the limestone, bowlders and fragments of this rock fall down the bluff or escarpment face on the clay. Hence the eighty feet of clay rarely has even one-fourth mile exposure width, while the Vola limestone projects in the form of a bench from the top of the bluff or hill, or remains as bowlders on the surface.

Vola limestone occurs exposed in the bed of San Gabriel river for one mile below Town's mill dam, until concealed by Eagle Ford shale. It also occurs along the banks of Brushy creek from the Balcones fault at Round Rock to very near the mouth of Channel creek.

UPPER CRETACEOUS SERIES.

dd. Eagle Pass (Ponderosa or Blue Marl) Division.
cc. Austin Limestone Division.
bb. Eagle Ford Shales Division.
aa. Red River (Lower Cross Timbers) Division.

The Upper Cretaceous, as a whole, may be classed as a marl. North of the Brazos river only do the basal rocks take the character of sandstone. Exclusive of the sand bed at the base of the Upper Cretaceous, which is occupied by the Lower Cross Timbers, the prevailing rock elements are clay, lime and sand, in the order given. Though the rocks vary in color and durability, resistance to destructive elements of erosion, amount of organic matter, relative quality of clay, lime and siliceous sand, they may all nevertheless be justly classed as a marl. With the exception of local indurations and nodular segregations, the beds are all composed of friable, yielding rock.

RED RIVER (LOWER CROSS TIMBER) DIVISION.

These rocks do not occur south of the Brazos river. Whether they have representatives in the Eagle Ford shales here, is as yet a question.

EAGLE FORD SHALES.

In the locality of the Lampasas-Williamson section, beds of the Eagle Ford shales are exposed only on San Gabriel river below Town's mill, and on Brushy creek, three miles below Round Rock. Elsewhere, between San Gabriel river and Brushy creek, the rock is concealed by surface soil and drift which prevails over a considerable portion of the Upper Cretaceous here.

These beds are beautifully exposed in bluffs ten to forty feet high, immediately below Town's mill and one mile below the mill, on San Gabriel river, and they show large lens-like lenticular bands of arenaceous limestone interstratified at the base with flaggy arenaceous and pyritous shale. Above this there follow stratified and laminated layers of bituminous dark blue shale, light yellow very calcareous shale, bright yellow laminated clay to calcareous chalky soft flagstones at the top. There are many shades of color from dark blue to bright yellow and white.

Ammonites sp. ind. occur in the lenses and lenticular bands of indurated lime at the base of the bed.

Fish bones and teeth are scattered in the arenaceous flaggy and pyritous shale. Flaggy layers contain numerous small undetermined *Ostrea*. A band of blue granular shale, near the center of the bed, contains many small brown scales, beautifully marked. Higher strata carry numerous individuals of a large flat *Inoceramus*. Fragments of fish bones and teeth can be detected throughout the whole bed. An occasional thin band is composed almost wholly of fragmentary fish remains. Upon striking this shale sharply with a hammer, or upon rubbing two pieces of shale briskly together, a feted odor as of bitumen or of crude petroleum is produced.

In Williamson county, as well as at all other points south of the Bosque river where it has been observed, the Eagle Ford shale rests upon the Vola limestone in perfect stratigraphic conformity.

AUSTIN LIMESTONE.

The study of these rocks upon the line of this section in Williamson county is not considered to apply to the bed generally. Instead, it is a local work in a special field of a thick deposit of limestone, inexhaustible almost, yet varying in its store of scientific interest and economic value. The known linear extent of this limestone in the State, as outlined by the Survey, is not less than six hundred miles, with an average width of six miles. Its area is therefore not less than three thousand six hundred square miles. The work then upon these beds in the locality here can be no more than an introduction to the work to be done before it can be said to be completed.

THICKNESS AND CHARACTER.—The exact thickness of the Austin limestone could not be accurately estimated on account of the disturb-

ances incident to the Balcones fault, which passes west of its border through Round Rock and Georgetown. Small faults, with throws both east and west, transect the beds at short intervals and cause the dips to vary to such a degree that they are not reliable. They vary locally, from 5 degrees toward the southeast to zero, and in a few instances are slightly reversed. By an estimate based upon the Eagle Ford shale, whose thickness could be determined, and which is beneath the Austin limestone, the base of the limestone was found to dip about south 30 degrees east nearly one hundred feet per mile. The average width of the limestone, on a level surface in the direction of the dip, is nearly six miles. The thickness, then, by the clearest estimate, is six hundred feet in Williamson county.

The rock is a comparatively firm chalky limestone at the base, marly to arenaceous lime in the central portion, and lime marl at the top. The whole is stratified in beds from six inches to ten feet thick, light blue to cream-colored before oxidation, and cream-colored to pure white after long exposure. There are rarely thin bands of white argillaceous blue lime, which crumbles readily on exposure. Along bluffs and banks of creeks these argillaceous bands form recesses by rapid disintegration, leaving the more indurated limestone layers projected in parallel benches. Even in the thick bed there is much variation in their resistance to weather, which is governed by the varying percentage of siliceous material of which they are composed.

From the base upward, for about two hundred feet, the limestone is in its purest state, and occurs in massive beds from two or three to ten feet thick, with borders of slightly argillaceous limestone. Typical exposures of this portion occur along the immediate bank of Brushy creek, from two and one-half to six and a half miles below Round Rock. A specimen from a massive ledge near the central portion, taken as an average specimen, after being compared with many others collected from various parts of this lower two hundred feet, presents the following component materials (analysis by Mr. G. H. Wooten):

ANALYSIS OF AUSTIN LIMESTONE—BASAL PORTION.

Water	.82
Silica	5.94
Lime	48.73
Magnesia	
Sulphuric acid	.42
Alumina	1.41
Ferric oxide	1.31
Carbonic acid	37.84
Potash	.20
Soda	2.60
Phosphoric acid	.142
Total	99.412

From this analysis it is seen that the rock is low in sand and clay, while the carbonate of lime approaches nearly eighty-five per cent.

In this part of the rock there are very many specimens of large *Inocerami*. On account of the transverse crystallization of their pseudomorphic shells, it was almost impossible to take them from the rock. An occasional *Ammonite* occurs associated with the large *Inocerami*.

ARENACEOUS HORIZON. —Beginning at the upper edge of the basal chalky zone, which crops out in Brushy creek, three miles southwest of Hutto, and continuing upon the rocks toward the southeast, the limestone becomes more arenaceous, and occurs in thinner beds. Two miles southwest of Hutto, it weathers into large oval bowlders along the creek banks. The intervening marly layers and the extensive joints which cross the creek in a north-south direction aids in the separation of the limestone into blocks. Large bowlders of several tons weight stand apart from the bed resting upon short necks of marly lime. This character continues exposed in the banks of Brushy creek for nearly four miles, presenting but little variation in character of composition, color or fossil fauna. As a rule this rock has a more dull blue earthy tinge than has the purer lime below.

Besides the *Inocerami* which occur in the lower zone, there are present in the arenaceous beds numerous *Ammonites*, *Nautili*, *Exogyra ponderosa*, *Gryphæa aucella*, *Pecten*, and *Trigonia* (?). In some of the layers occurring in the creek bank, south of Hutto, fragments of *Inocerami* compose considerable portions of the rock. Occasionally *Radiolites austinensis* are found.

The upper layer of the arenaceous lime beds dips beneath the base of Brushy creek, opposite Shiloh School House, nearly three miles southeast of Hutto.

An average specimen of the arenaceous zone of the Austin limestone shows the following composition, according to the analysis of Mr. G. H. Wooten:

ANALYSIS OF AUSTIN LIMESTONE—CENTRAL ARENACEOUS PORTION.

Water	.51
Silica	10.32
Lime	45.31
Magnesia	Trace.
Sulphuric acid	1.04
Alumina	5.41
Ferric oxide	1.15
Carbonic acid	34.44
Potash	.17
Soda	2.07
Phosphoric acid	.218
Total	100.638

In this case the percentage of sand is ten per cent of the mass, five per cent more than the percentage of sand in the basal bed, and the lime has decreased an equal percentage.

AUCELLA HORIZON.—One-fourth mile above Shiloh School House, on the south side of Brushy creek, there is a bluff sixty feet high exposing Austin limestone above the arenaceous zone. The rock is less indurated than the limestone below. Upon exposure it "slacks" and crumbles, falling into lumps. The following is a section of the bluff in descending order:

4. Chalky lime, breaking into lumps, and yellow pulverulent earth, containing great numbers of *Exogyra ponderosa* in sizes of from one inch to six inches in diameter. At the base fossils of *Exogyra ponderosa* are commingled with very small *Grpyhæa aucella* . . . 20 feet.
3. Chalky limestone, bearing great numbers of *Gryphæa aucella* with few *Exogyra ponderosa*, alternating with marly lime. Layers are from a few inches to two feet thick . . . . 20 feet.
2. Alternating chalky marly beds, same as No. 3. Few *Exogyra ponderosa*, *Gryphæa aucella* and *Inocerami* occur here . . . . 20 feet.
1. Fossiliferous arenaceous limestone, which is the final layer of the arenaceous bed. It contains great numbers of *Inocerami* fragments, *Nautili* and *Ammonite* . . . .

MARLY LIME ZONE.—The remaining portion of the Austin limestone is best exposed in the high bluffs on San Gabriel river, one and two miles below Jonah postoffice. This zone forms the bond or transition bed, lithologically, between the Austin limestone and the Blue Marl.

The bluffs above cited exhibit beautiful exposures of marly lime strata succeeded by layers of lime marl, the two separated by flaggy bands of arenaceous marl three to four inches thick. From the base of the bluff upward twenty feet the marly lime is clearly stratified in layers of from a few inches to two or three feet. The layers weather irregularly, the more marly falling away and leaving the pure lime with projecting edges. Upon fresh fracture the marly lime shows a dull blue color, but on weathering it turns a bright yellow, from oxidation of the component pyrites of iron.

These strata carry large *Exogyra ponderosa*, and an oyster resembling *O. subovata*, and a small narrow-beaked oyster.

The arenaceous flaggy layer at the upper limit of the marly lime is considered as the limit of the Austin limestone. Above this layer the rock partakes of the character and fauna more strictly of the Blue (Ponderosa) Marl.

ANALYSIS OF AUSTIN LIMESTONE—UPPER DIVISION.*

Water	1.27
Silica	11.31
Lime	42.61
Magnesia	...
Sulphuric acid	1.13
Alumina	5.78
Ferric oxide	1.72
Carbonic acid	33.86
Potash	.33
Soda	2 36
Phosphoric acid	.131
Total	100.501

Outside of the immediate valley of the San Gabriel river and Brushy creek the Austin limestone has very little exposure. Upon the high land between these valleys there is a heavy black residual and drift soil upon the limestone, except on an occasional high point where the degraded lime appears at the surface. The surface is either nearly level or gently rolling.

BLUE ("PONDEROSA") MARL.†

The Blue Marl succeeds the Austin limestone, and presents a series of marl beds remarkable for their thickness, consistency and structure of deposit. Along the valleys of the San Gabriel river and Brushy creek, in Williamson county, where the only detailed section has been made north of the Rio Grande, this marl division separates into four lithologic subdivisions or heads, in the following order from the base upward:

1. THE CHALK MARL.—This bed, resting upon the marly lime bed of the Austin limestone, is nearly one hundred feet thick, and is crowded with many fossils of *Baculites*, *Ammonites*, *Ostrea larva*, *Anomia*, *Inocerami*, *Pecten* and *Ostrea*. Of all these the *Ostrea larva* is most abundant, and is the type of the bed. Its first known occurrence in the Cretaceous is at the base of this bed.

The marl is a dull yellowish blue in color where it has not been disintegrated; but as disintegration goes on, it changes through various hues of yellow up to the black soil at the surface. The whole bed is stratified, but more distinctly so at the base, where it begins in thin arenaceous bands. As the ascent of the bed is made, the layers become thicker and less arenaceous, until the top is reached in a massive homogeneous blue clay marl. The parting line between this bed and the one succeed-

* Analysis by G. H. Wooten.

† A portion of the Eagle Pass Division of the Rio Grande Region. Bulletin of the Geological Society of America. Notes on the Geology of the Valley of the Middle Rio Grande, by E. T. Dumble.

ing it is not perceptible. The lines of stratification become less distinct, and the yellowish blue shades of the chalk marl blend into the deeper blue of the massive.

ANALYSIS OF AN AVERAGE SPECIMEN OF CHALK MARL.*

Water	1.10
Silica	15.98
Lime	38.86
Magnesia	...
Sulphuric acid	.83
Alumina	6.18
Ferric oxide	2.29
Carbonic acid	31.74
Potash	.15
Soda	2.84
Phosphoric acid	.108
Total	100.078

The relative amounts of sand and clay, as determined by the percentages of silica and alumina, have increased over that of the marly lime below, while the percentage of lime has decreased nearly proportionately. The relative amounts of potash, soda and phosphoric acid remains practically the same.

Good exposures occur in bluffs one to two miles below Jonah post-office on the San Gabriel river. The bed is concealed on Brushy creek for one mile below Shiloh School House, three miles below Hutto. It occurs in the banks of ravines tributary to Mustang creek, two miles above Taylor, and also along the International and Great Northern Railway on the south side of the creek valley. Outside the creek valleys, a heavy black residual soil occupies the locality of this bed, except where covered by drift deposits.

2. PONDEROSA MARL.—The second on the blue marl series may be designated as Ponderosa Marl because of the prevailing abundance of this fossil within its limits. This bed has a thickness of nearly one thousand feet. It is practically free from stratification, or bed planes, and has but little variation of lithologic character from base to top of the bed. On weathering, the dark blue marly clay changes from blue, through shades of yellow, and then to brown, as it verges into soil, showing in the first stages of disintegration obscure fine laminations. Gypsum crystals of selenite form in the marl at a certain stage of its decomposition, upon fresh exposures in the face of the bluffs and in banks of the streams.

The lower half of this bed does not abound so abundantly in fossils as does the upper portion, though there are present numbers of *Inocerami*, *Exogyra ponderosa*, *Ostrea larva*, and small *Ostrea* sp. ind.

*Analysis by Mr. G. H. Wooten, of the Survey.

ANALYSIS* OF MARL FROM THE LOWER PORTION OF THE BED.†

Water	4.36
Silica	45.02
Lime	14.26
Magnesia	. . .
Sulphuric acid	.97
Alumina	16.17
Ferric oxide	4.78
Carbonic acid	10.36
Potash	.975
Soda	3.22
Phosphoric acid	.113
Total	100.228

From the above analysis it will be seen that the relative amounts of sand and clay, as determined by the percentages of silica and alumina, still increase as we ascend into the marl, while the lime decreases. The amounts of potash and iron also increase.

Near the center of the bed there are broken bands or irregular collections of yellow calcareous clay nodules, often filled with a network of calcite veins. Some of the nodules are large turtle-shaped masses, while others have the form of potatoes with protuberances on their sides.

Ammonites, *Baculites*, *Scaphites* and *Helioceras* occur, included in some of the nodular masses of argillaceous lime. The clay itself in this portion of the bed is not so rich in fossils as it is in either the lower or upper portion, yet there are present casts of *Inocerami*, shells of *Ostrea* sp. ind., and *Ammonites*.

This portion of the bed occurs on Brushy creek at Rice's crossing.

Below is an analysis of marl from the face of the high bluff at Rice's crossing:

ANALYSIS OF MARL FROM CENTRAL PART OF PONDEROSA BED.*

Water	3.68
Silica	48.72
Lime	11 79
Magnesia	Trace.
Sulphuric acid	2.21
Alumina	16.10
Ferric oxide	4.87
Carbonic acid	8.30
Potash	1.14
Soda	3.07
Phosphoric acid	.109
Total	99.989

*Analysis by Mr. G. H. Wooten.

†Specimen of marl selected from fresh exposure in bank of creek one-half mile southeast of Taylor.

Great numbers of *Exogyra ponderosa* and *Ostrea larva* appear in this bed on Brushy creek, at Baker's crossing, nearly two hundred feet above the nodular zone at Rice's crossing, and continue in the marl for a distance of one mile along the creek.

The *Exogyra ponderosa* here attains its maximum size and abundance. The fossils are so numerous as to be drifted into shoals in the creek. Numbers of a small, fragile, narrow-beaked oyster occur here; also *Anomia* and a small *Gryphæa*(?).

There is slight apparent change in the character of the marl on ascending to this point. It is of a more earthy blue, and appears to contain less clay and more organic matter.

ANALYSIS* OF MARL.†

Water	3.77
Silica	28.34
Lime	29.76
Magnesia	
Sulphuric acid	1.04
Alumina	7.50
Ferric oxide	3.92
Carbonic acid	22.80
Potash	.29
Soda	2.04
Phosphoric acid	.118
Total	99.578

Though the siliceous material in the form of sand runs as high as forty-eight per cent in this bed, yet it is not perceptible to the eye. A hand specimen has a harsh touch on fresh fractured surface, by which the presence of sand in microscopic grains can be detected. The presence of sand cannot be detected by the senses in the rich black residual soil upon the marl, except when crushed between the teeth.

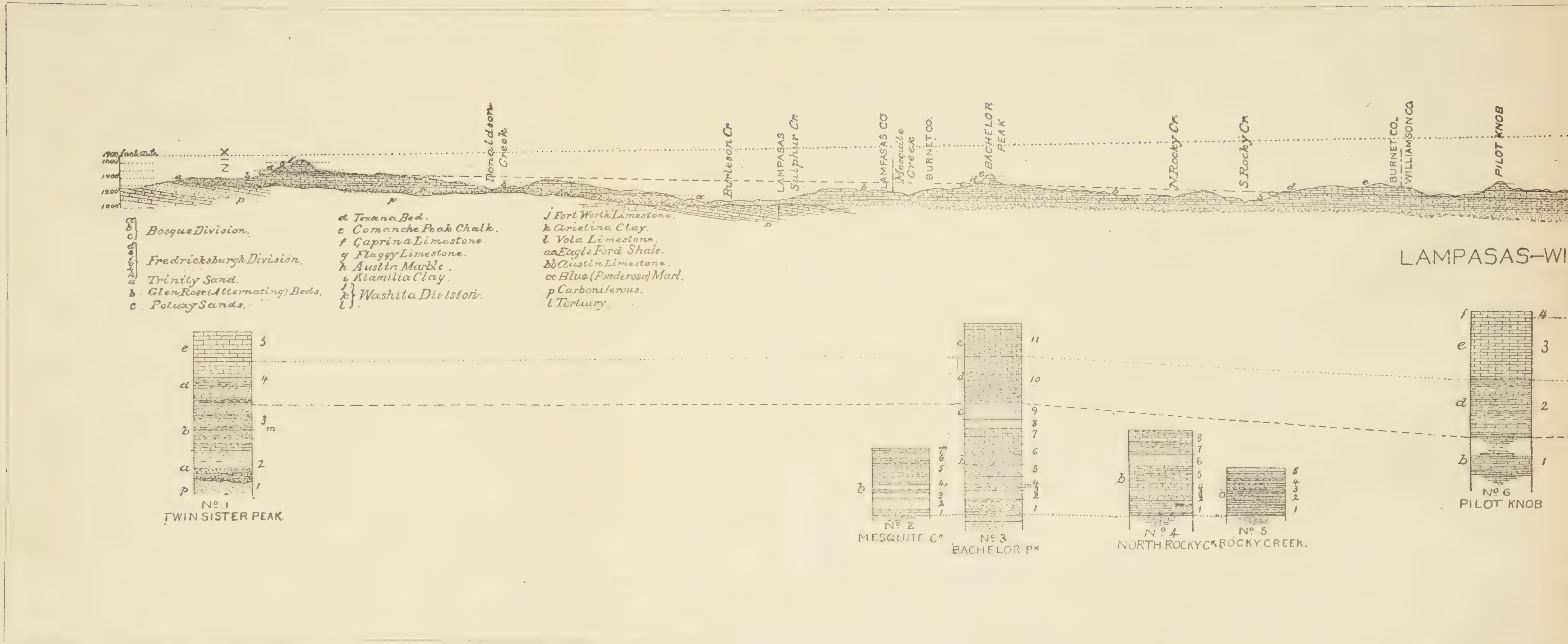
Upon approaching the upper limit of this bed, stratification planes between thick layers become perceptible.

Exposures of this bed occur in the banks and bluffs of Brushy creek from one mile below Shiloh School House to the Missouri, Kansas and Texas Railroad. One and two miles below Rices' crossing, and at the crossing, there are bluffs of marl exposed, forty to fifty feet thick. Below Rice's crossing exposures are confined to the immediate creek banks.

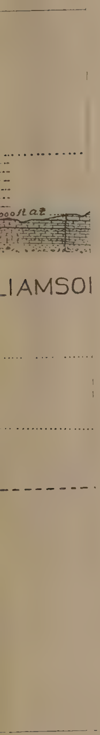
The bed occurs in the banks of San Gabriel river from three miles east of Jonah postoffice to the Williamson county line. From Taylor southeast it crops out in the banks of Mustang creek to a point one mile above its mouth.

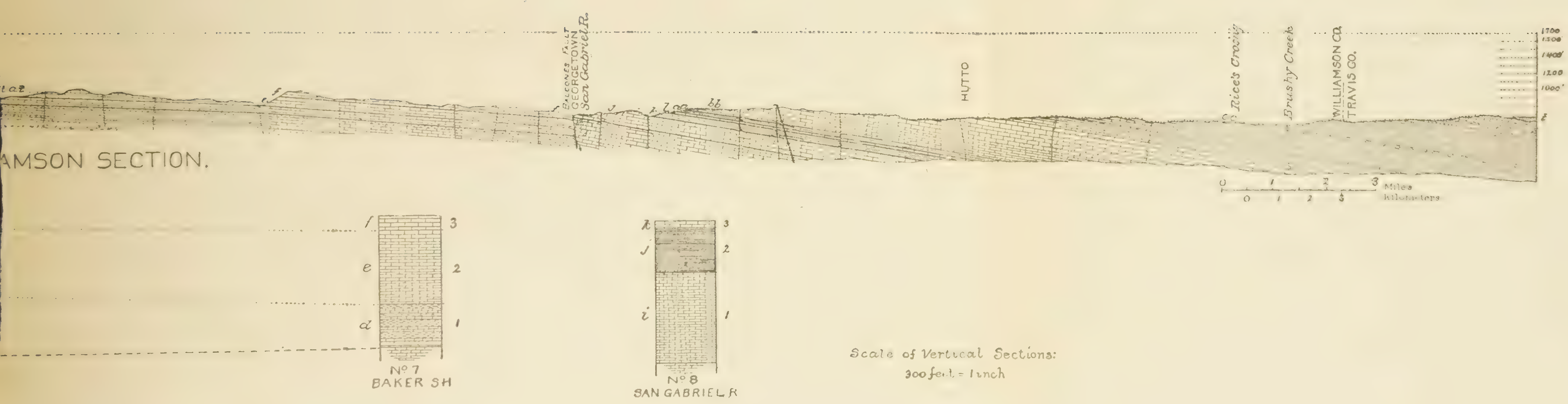
* Analysis by G. H. Wooten.

† From upper edge of Ponderosa zone one mile above Missouri, Kansas and Texas Railway, on Brushy creek.



Donaldson Creek
Burleson Cr
LAMPASAS
Sulphur Cr
LAMPASAS CO
Mesquite Creek
BURNET CO.
BACHELOR PEAK
N. Rocky Cr.
S. Rocky Cr.
BURNET CO.
WILLIAMSON CO.
PILOT KNOB
Bosque Division.
Fredricksburgh Division.
a Trinity Sand.
b Glen Rose (Alternating) Beds.
c Poluxy Sands.
d Texana Bed.
e Comanche Peak Chalk.
f Caprina Limestone.
g Flaggy Limestone.
h Austin Marble.
i Kiamilia Clay.
Washita Division.
j Fort Worth Limestone.
k Arietina Clay.
l Vola Limestone.
aa Eagle Ford Shale.
bb Austin Limestone.
cc Blue (Ponderosa) Marl.
p Carboniferous.
t Tertiary.
LAMPASAS—WI
Nº 1
TWIN SISTER PEAK.
Nº 2
MESQUITE Cº
Nº 3
BACHELOR Pᴷ
Nº 4
NORTH ROCKY Cᴷ
Nº 5
ROCKY CREEK.
Nº 6
PILOT KNOB





BALCONES FAULT
GEORGETOWN
San Gabriel R.
HUTTO
Rice's Crossing
Brushy Creek
WILLIAMSON CO.
TRAVIS CO.
AMSON SECTION.
Miles
Kilometers
Nº 7
BAKER SH
Nº 8
SAN GABRIEL R
Scale of Vertical Sections:
300 feet = 1 inch

ANALYSIS OF (GREENSAND) MARL* FROM THE CENTRAL PORTION.

Water	5.35
Silica	60.82
Lime	3.66
Magnesia	
Alumina	16.05
Ferric oxide	5.25
Carbonic acid	2.85
Potash	1.75
Soda	2.94
Sulphuric acid	1.06
Phosphoric acid	.187
Total	99.917

Strata of the glauconitic bed crop out at intervals along Brushy creek, from Lawrence crossing below the Missouri, Kansas and Texas Railway to the International and Great Northern Railway crossing east of Thorndale. Beneath the International and Great Northern Railway bridge over Brushy creek there is a beautiful exposure of greensand marl in a bluff. Casts of *Baculites*, gasteropods and bivalves occur here, mingled with pebbles of lime, flint and silicified wood.

COLUMNAR SECTIONS.

These sections are drawn upon Plate XIV beneath their respective points of location on the Lampasas-Williamson section. The details for the columnar sections were obtained upon the ground by the writer and Mr. S. Leverett.

The bands or layers of rock designated by the numbers 1, 2, 3, etc., respectively, from the base of the section upward, are so separated for convenience of description.

SECTION 1. TWIN SISTERS PEAK.

Section 1 includes Cretaceous rocks from the base of the Caprina bed to the Carboniferous in Twin Sisters Peak, and are given in descending order.

5. Comanche Peak chalky limestone, from the cap of the peak to the top of the Texana bed. The rock is soft, white, heavily bedded, and almost pure limestone, except the cap rock, about eight feet thick, which is an indurated chalky limestone . . . . 50 feet.

Numerous fossils of *Toxaster texanus*, *Diadema* and gasteropods occur at the base of the bed.

4. Texana bed, upper to lower limits of the occurrence of the fossil *Exogyra texana*. The upper twenty-five to thirty feet is a chalky limestone very much like that of the Comanche Peak. Below this, chalky white to yellow limestone alternate with a marly lime. *Exogyra texana* and *Gryphæa pitcheri* shells are very numerous and well preserved near the middle of the bed, but become smaller

* Analysis by G. H. Wooten.

and less numerous below and above. *Ammonites acuto-carinatus*, *Cyprimeria crassa*, *Arca*, *Toxaster texanus*, *Diadema texanum* and gasteropods occur in the upper chalky limestone . . . . 80 feet.

3. Glen Rose (Alternating) beds. Limestone, lime marl, and calcareous sand alternating in layers from two to three feet to as many inches. Toward the base the rocks become more arenaceous until the sandy marl blends with the sand. (m) Twenty feet above the base there are many large inclusions of calcite crystals in the marly lime. Fossils of a small variety of *Exogyra texana* occur about fifteen feet above the base of the bed. *Cardium mediale*, many other bivalves, and gasteropods occur also in the lower portion . . . .
2. Trinity bed, resting upon Carboniferous sandstone. The upper twenty feet is a stratified calcareous sandstone. Below this there are about thirty feet of loosely packed materials composed of typical "pack-sand," grit and calcareous sand, stratified and in part false-bedded. The basal twenty feet is a conglomerate of limestone, quartz and flint, cemented in an argillaceous, calcareous sandy matrix, purple, yellow, brown and red in color. Many of the cobblestones composing the conglomerates are but slightly worn . . . . 70 feet.
1. Carboniferous sandstones in thin beds. This sandstone is brown and false-stratified, dipping two to three degrees northwest . . . .

SECTION 2. MESQUITE CREEK.

The rocks illustrated by this section belong to the Glen Rose series, are exposed in the bluffs of Mesquite creek from one-fourth to two miles below the Lampasas-Georgetown road. The strata are given in descending order from 7 to 1:

7. Hard semi-crystalline limestone . . . . 5 feet.
6. Marly clay and arenaceous limestone, weathering light yellow. *Cardium mediale* occurs here very near the base . . . . 20 feet.
5. Arenaceous limestone . . . . 20 feet.
4. Arenaceous limestone and calcareous sandstone, becoming more limy toward the top, capped with a hard limestone layer . . . . 30 feet.
3. Soft blue calcareous laminated sandstone, weathering into flakes . . . 8 feet.
2. Brown to yellow calcareous sandstone, varying from hard to loosely packed, resembling that in the upper Trinity in Twin Sisters Peaks. 20 feet.
1. Hard semi-crystalline limestone . . . . 8 feet.

SECTION NO. 3.

Bachelor Peak, in descending order, beginning in Comanche Peak limestone at the top of the peak, and ending in the Glen Rose bed seen at the base of Mesquite creek on the north side:

11. Comanche Peak chalky limestone, from the summit of the Peak to the upper limit of the Texana bed . . . . 60 feet.
10. Texana bed. This is exactly similar to No. 4 in Twin Sisters Peak, which is the same bed . . . . 80 feet.
9. Soft yellow laminated sands. This is the representative of the Paluxy sands, which appear fully developed north of the Leon river. It is not persistent here, but varies from one locality to another in thickness, in amounts of lime and in stratification . . . . 30 feet.
8. Calcareous sandstone . . . . 15 feet.

7. Arenaceous limestone . . . . 15 feet.
6. Hard limestone in the upper part, limestone interbedded with limy marl below . . . . 50 feet.
5. Arenaceous lime, limestone, and soft yellow calcareous sand rock, alternating in beds . . . . 20 feet.
4. Blue marly limestone, which weathers to a yellow color on long exposure . . . . 20 feet.
3. Hard limestone . . . . 5 feet.
2. Soft yellow to gray calcareous sand rock . . . . 15 feet.
1. Soft gray to white limestone, very arenaceous and clearly stratified. It is interbedded with a very calcareous soft blue to gray marl. *Cardium mediale*, *Arca* and numerous other bivalves, *Goniolina* (?) and *Natica pedernales* abound in great numbers . . . . 15 feet.

A bed of blue arenaceous limestone was partly exposed below No. 1 in the bed of the creek. In this limestone there were many specimens of *Caprotina* and *Monopleura*.

SECTION NO. 4. NORTH ROCKY CREEK.

The rocks of this section occur exposed along the valley sides and bluffs of the creek on the line of the Lampasas section. Descending order of occurrence from eight to one:

8. Marly and flaggy limestone, alternating. The hard limestone layer contains fragments of oyster shells . . . . 20 feet.
7. Lime marl, weathering light yellow on exposure . . . . 20 feet.
6. Sandstone strata, soft yellow and laminated . . . . 20 feet.
5. Arenaceous limestone . . . . 30 feet.
4. Hard massive limestone . . . . 10 feet.
3. Calcareous sand, stratified . . . . 10 feet.
2. Arenaceous limestone, in massive beds . . . . 10 feet.
1. This member with No. 2 is exposed in the bluffs of North Rocky creek below the Lampasas-Georgetown road, and is divided into several sub-members, as follows:

d. Marly limestone . . . . 15 inches.
c. Massive arenaceous limestone . . . . 6 feet.
b. Blue lime marl . . . . 3 feet.
a. Hard limestone, with marly layers intermediate. This layer abounds in *Cardium mediale*, *Natica pedernales*, *Serpula*, *Goniolina* (?) and *Arca* . . . . 6 feet.

In the upper layer of No. 1 there are numerous large inclusions and nodules of celestite crystals. Specimens are beautiful and easily obtained.

SECTION NO. 5. SOUTH ROCKY CREEK.

Numbers of high bluffs occur on South Rocky creek above and below the crossing of the Lampasas-Georgetown road. The following is a section of a high bluff in descending order, three miles below the road crossing:

5. Moderately soft limestone and thin marly lime bands, in alternating layers . . . . 20 feet.
4. Limestone, weathering in porous masses from the disintegration of the rock of fucoidal root-like casts . . . . 4 feet.
3. Alternating, thick beds of soft limestone and thin bands of marly lime. 15 feet.
2. Marly lime, with occasional *Arca*, *Cardium*, etc. . . . . 15 feet.
1. Semi-marly limestone, weathering into marl and conchoidal shell fragments . . . . 25 feet.

The upper portion of No. 1 contains numerous *Cardium mediale*, *Natica pedernales*, *Arca*, *Trigonia*, *Goniolina* (?), and *Serpula* fossils. Nodules and large crystals of celestite occur in numbers 1, 2 and 3.

SECTION NO. 6—PILOT KNOB.

From the top of Pilot Knob to the bed of San Gabriel river below Gabriel Mills:

4. Caprina limestone. A remnant of the basal flint horizon remains, forming the cap rock of the peak. Many fragments of flint occur upon the surface and in the indurated limestone . . . . 10 feet.
3. Comanche Peak limestone. Debris from the Caprina beds and from the surface weathering conceals surface exposures upon the slopes of the peak . . . . 110 feet.
2. Texana bed, which is exposed in the slopes and breaks of the San Gabriel river valley, between Pilot Knob and Gabriel Mills. There is but little if any variation in the bed at this locality and in that described under No. 10 of Bachelor Peak section . . . . . 100 feet.
1. Glen Rose (Alternating) bed. These rocks occur along the bluffs at the border of the river valley, and in bluffs of creek basins. The upper portion here is poorly exposed. Thickness of alternating beds from the base of the Texana bed to the bed of the river . . 60 feet.

Bluffs thirty to fifty feet high occur on the river three-fourths of a mile above Gabriel Mills. At the base of the bluff there are calcareous sand and marly lime strata, containing *Exogyra texana* (small var.). One mile below the same horizon occurs in the bank of the river, and immediately below it there are many *Cardium mediale*, *Trigonia crenulata*, *Diadema texanum*(?), *Arca*, and *Natica pedernales*.

SECTION NO. 7—BAKER'S SCHOOL HOUSE.

The location of this section is on the San Gabriel river twelve miles above Georgetown. High bluffs of Caprina, Comanche Peak and Texana limestone form a wall along the sides of the narrow valley opposite Baker's School House.

3. Caprina limestone, containing *Caprina crassifibra* and *Caprotina* fossils with flints . . . . 25 feet.
2. Comanche Peak chalky limestone. The upper twenty-five to thirty feet of limestone is in beds three to eight feet thick. The middle portion is soft, white and chalky . . . . 120 feet.
1. Texana bed, partially exposed seventy feet above the bed of the creek . . . .

SECTION NO. 7 "A."

(Omitted from plate.)

Section of the Caprina bed as it occurs at Georgetown and along Brushy creek above Round Rock:

10. Soft yellowish limestone, which contains *Exogyra texana* and other undetermined lamellibranchs . . . . 8 feet.
9. Limestone, hard and rather massive, which bears *Caprotina* fossils . . 7 feet.
8. Massive yellow to white, almost pure chalky limestone, with bands and lense nodules of black flints . . . . 13 feet.
7. *Hippurites flabellifera* bed . . . . 4 feet.
6. Limestone, dull blue in color, which contains many *Caprina crassifibra* and *Caprotina* fossils . . . . 3 feet.
5. Chalky limestone, in massive thick strata* . . . . 13 feet.

In some localities there is a band of black to gray flint nodules between members five and six.

4. Limestone strata, containing brown flints. Very many fossils of *Caprotina* occur in the limestone and imbedded in the flint nodules near the upper edge of this member . . . . 25 feet.
3. Flaggy limestone, heavy layers, some of which are quite siliceous. Near the upper and lower edges there are many large white to light agatic flints . . . . 25 feet.
2. Siliceous hard limestone, in strata from three to five feet thick. On fresh fracture this rock has the appearance of a hard crystalline limestone, but when weathered fine clear grains of quartz sand appear on the surface. In this member there are thin bands of fossiliferous indurated flinty limestone resembling quartzite . . . . . 35 feet.
1. Massive chalky limestone, which contains many *Caprotina* fossils and many *Caprina crassifibra*. Upon weathering, the *Caprina* fossils disintegrate rapidly leaving the limestone a porous honeycombed rock . . . . 20 feet.

SECTION NO. 8. SAN GABRIEL RIVER.

The rocks of this section are exposed in bluffs of San Gabriel river from Georgetown east to Town's mill.

3. Vola limestone . . . . 10 feet.
2. Arietina clay . . . . 75 feet.
1. Fort Worth limestone, all of which is exposed except a small portion at the base, which is nearly concealed by the disturbance of the Balcones fault . . . . 150 feet.

POST-CRETACEOUS DEPOSITS.

DRIFT OF THE HIGH LAND.

There is a deposit of gravel, sand and cobblestone, spreading mantle-like over the edges of the eroded strata of the Upper Cretaceous in Williamson county. Deposits similar in character of materials and

*In the bluffs of Barton creek some of the layers of this member contain beautiful calcified fossils of *Caprotina*, bivalves and corals, which weather from the face of the rock in the most unique manner.

identical structure* occur in an almost continuous belt from the Rio Grande to the Trinity river. In the region of the locality first cited it has been studied critically only between San Gabriel river and Brushy creek. This region belongs to the hydrographic basin of the Brazos river. In the region of the Rio Grande and Nueces river the drift was observed upon Tertiary strata. Tertiary rocks beyond the immediate Cretaceous-Tertiary border were not studied in Williamson county.

The topography of the drift area is a high land, gently sloping eastward and toward the north and south into the valleys of the San Gabriel river and Brushy creek. Should the covering of drift be removed, the topography would be but little changed. The only change would be to sharpen the features, for upon the western and highest portion of the drift the heavier deposit is upon the flank of the high land and near the river and creek basins.

Upon the higher divide south of Georgetown there is a thin covering of gravel and cobblestones on the surface and in the soil to the depth of a foot and less. The drift continues as a thin layer along the crest of the dividing ledge southeast between the San Gabriel river and Brushy creek, beyond the Missouri Pacific Railway, where it increases in thickness, becoming quite a thick bed.

At Taylor the drift is several feet thick on the high points. Eastward from Taylor, between Turkey and Brushy creeks, this deposit becomes thicker, until at a point ten miles east of Taylor it is twenty feet thick.

The valleys of San Gabriel river, Brushy creek and its tributaries, Battleground, Mustang, and Turkey creeks, have been eroded through the drift and down into Cretaceous rock, leaving it flanking their sides. (See figure 10.) A residual flint cobblestone remains in places along the valleys of the streams where it has fallen, as the softer marls and limestones eroded beneath them.

Wherever the exposures of this drift could be found, whether in railway cuts, in bluffs, or in well sections, the action of rapid and shifting currents was depicted in the structure of the beds. Heavy cobblestones of calcareous flint and limestone, six inches and more in diameter, are thrown in with sand, grit and pebbles of worn Cretaceous fossils and lime. Then there are lenticular bands and lenses of till-like silty lime, which look like they had been exposed once to partial degradation after deposition.

CHARACTER OF THE MATERIAL COMPOSING THE DRIFT.

The drift occurring between the Balcones fault (which extends through Georgetown and Round Rock) and the Missouri, Kansas and Texas Railway is composed solely of debris from Lower Cretaceous rocks.

*Observed and studied by the writer in the valley of every river from Laredo, in Webb county, to Terrell, in Kaufman county.

It is a heterogeneous, rarely indurated mass of subangular cobblestones and pebbles of Cretaceous flint, limestone, and fossils. Occasionally beds are found projecting from the hillsides above the river valley. In such cases the conglomerate is found to contain a slightly ferruginous lime cement. Below an elevation of about six hundred feet above tide level, by the United States topographic sheets, an element of foreign drift, such as white and gray quartz, black and red jasper, in well-worn pebbles, and fragments of silicified wood enter into the deposits. Still, pebbles of Cretaceous flint, lime and rolled fossils form the body of the drift. As a whole, however, the material is finer, and the sorting of silt, sand and pebbles into beds is more distinct.

Wells dug in this drift to depths of twenty or thirty feet show an increase in size of pebbles downward. Also, in sections of wells examined between Taylor and Thorndale and between Turkey creek and San Gabriel river valleys, in Williamson county, show a decrease in amount of foreign drift downward from the surface to the base on the blue marl, though this foreign element is present throughout the deposit here.

Upon disintegration, the drift forms light yellow to white marly rock, and in the later stages of decomposition white chalk-like calcareous concretions. Furthermore, the drift at this stage has a mottled white and buff surface coloring. In all essential particulars there is little difference between this mixed foreign and Cretaceous drift and that adjacent to the valleys of the Medina, Frio, Leona and Nueces rivers, along the Cretaceous and Tertiary borders.

From the data obtained in the study of this drift, it seems evident that (1) the Cretaceous element was transported from the west down the valleys of the San Gabriel river and Brushy creeks, since that time the established drainage of these valleys; (2) that, at the time these deposits were formed, the volume of flow of water was much greater than at present; (3) that at a certain period during the deposition there were transverse currents, or else from valley to valley a commingling of the floods of the rivers, thus introducing the foreign element, which also occurs in the valleys of the Colorado and Brazos rivers; (4) that it is contemporaneous, in part at least, with the Reynosa beds,* since it has a stratigraphic resemblance to those beds, and almost a direct continuation; (5) and that we know it is of post-Miocene-Tertiary age, on account of its unconformability upon eroded strata of the Miocene-Tertiary.

SECOND BOTTOMS.

There is a more recent deposit, forming a plane and terrace between the immediate flood basins of the river and creek valleys and the primary terrace formed by the high land drift at their outer limit.

* Bulletin of the Geological Society of America, Vol. 3, pp. 229 and 230. Notes on the Geology of the Middle Rio Grande, by E. T. Dumble.

This deposit forms the second river or creek bottom of a rich brown to black sandy loam soil, underlain by silty deposits, which in turn rest upon gravel and pebble beds.

Marls of the upper Cretaceous are generally exposed in the primary terrace at the outer limit of the second bottoms.

Figure 10.

Section showing relations of Blue Marl drift and river silt and gravel of first and second bottoms.

a. Blue (Ponderosa) marl. b. Drift of the high land. c. Second bottom gravel and silt. d. First bottom.

Second bottoms are not well developed on the south side of the San Gabriel river above a point four miles west of the Williamson and Milam county line. At this point the second bottom begins and soon widens out to a mile or a mile and a half, forming a plain of very fertile lands. About the same relative point on Brushy creek the second bottom begins, and parallel to the creek runs to its junction with the San Gabriel river.

The pebble beds at the base of the second bottom deposits are similar to those of the second phase of the high land drift, and are composed of pebbles of Cretaceous flint, limestone and fossils, with a sprinkling of foreign drift worked over from the high land.

The first bottom is now in process of erosion or formation by the rivers and creeks. In this region, where the rocks are limestones and marls, the soil of the first bottom or flood basin is a black sticky humus laden with silt, except upon the immediate border of the stream, which is a little elevated and sandy. The soils of both the first and second bottoms are exceedingly fertile.

ECONOMIC GEOLOGY.

ARTESIAN WATER.

The conditions which govern the flow of artesian water are understood in a general way by a great many, but the source of supply for any given locality is known to very few. An erroneous idea prevails that artesian water can surely be obtained anywhere, provided a well be bored to a sufficiently great depth. It is thought also by some that if their neighbors can procure artesian water they can do likewise with equal facility, which may or may not be possible. The lack of proper knowledge of

flowing wells in general and the amount of flow, and the depth to which wells must be bored to obtain water in special localities, causes much loss of both time and money in useless expenditure while prospecting. Lack of knowledge also prevents the boring of artesian wells where an abundant supply is within easy reach.

In the region of the artesian water area north of the Colorado river, it is possible to estimate approximate depths for flowing wells, and closer estimates may be made upon the Grand Prairie between the upper and lower Cross Timbers north of the Brazos river, and in the area of the same belt of hard limestone between the Colorado and Brazos rivers; but estimates are less reliable upon the "black land" prairie between a line drawn through Sherman, Dallas, Waco and Austin, and the timber belt of the Tertiary.

The area wherein flowing wells can be obtained north of the Colorado river is estimated to be not less than twenty-one thousand square miles, or thirteen million four hundred and forty thousand acres. Within this area artesian wells can be obtained at depths of from less than one hundred to four thousand feet.

In order that there may be flowing wells three conditions are necessary, viz: 1. There must be a porous stratum, such as a pervious sand or conglomerate. 2. Above this porous water-bearing stratum there must be an impervious bed of rock, through which water cannot readily pass. 3. The source of the water supply or the outcrop of the water-bearing stratum must be higher than the top of the well.

SOURCES OF ARTESIAN WATER SUPPLY.

The water-bearing sand beds which supply the flowing wells in this artesian area are the Trinity, Paluxy and Red River beds.

The impervious strata above the Trinity and Paluxy beds are the Glen Rose and Texana limestone beds respectively. The Eagle Ford shale overlies the Red River bed, which is occupied by the lower Cross Timbers, and forms an impervious stratum.

The Red River sand does not occur south of the Brazos river, hence it does not enter into the discussion of artesian water in Lampasas, Burnet and Williamson counties. The Paluxy sand is not well developed south of the Leon river, and it is impregnated with clay, soluble salts of magnesia, strontia and other mineral matter, which unfits it for a successful water-bearing stratum. The Trinity sand remains alone as the source of supply for flowing wells in this region, and its extent here is not such as would afford either an abundant supply or a first-class quality of water, were it not a direct continuation of beds more favorably situated. In the first place its areal outcrop, or catchment area, is small, rarely more than a half mile in width, and often less. In the second place it has a variable structure, being composed of conglomerate with ferruginous and calcareous matrix, often partially in-

durated, ferrugino-calcareous sands, and indurated arenaceous limestone, which contains in places considerable quantities of iron sulphide.

In the southern portion of Lampasas county the Trinity bed is quite thin, and in places almost entirely absent, which gives little or no source to water for flowing wells in that region. Here also the conglomerate is so indurated that it will admit very little passage for water.

LOCALITIES FOR FLOWING WELLS.

From the great artesian area, wherein it is possible to obtain a flowing well at any point, arms of limited extent run westward up the river and creek valleys toward the catchment area, or exposure of water-bearing stratum.

West of a line drawn through Round Rock, Georgetown, Corn Hill, and Salado, to the Lampasas river north of Salado, it is not possible to obtain a flowing well except in the immediate valleys of the principal streams, and in these valleys it is possible only to a limited extent.

Along the immediate valley of the Lampasas river, from near the Hamilton county line southeastward, the conditions are suited for flowing wells of a few thousand gallons daily supply. Flowing water from wells may be obtained in the valleys of Simms and School creeks for nearly ten miles above their mouths. There is no possibility of obtaining artesian water beyond two or three miles above the mouth of Sulphur creek, and there only in small flows.

Small flows from bored wells may be gotten in the valleys of Mesquite and Rocky creeks for nearly six miles from Lampasas river.

For any of the locations above given it will rarely be necessary to excavate more than two hundred feet to obtain a flow, and often less than two hundred feet will suffice. The flow of water from wells here will not be great, but will be ample for culinary and farm purposes. It will not be sufficient, however, for irrigation unless it be very limited.

In the valley of the North Fork of San Gabriel river, from Georgetown to the Burnet county line, flowing wells may be obtained at depths from nearly six hundred feet at Georgetown to less than four hundred feet at the county line.

Near Georgetown the flow will most probably be quite abundant; but, as the valley is ascended, it will grow weaker until the water will only just reach the surface.

Flowing wells need not be expected in the valley of the South Fork of the San Gabriel river above the Austin and Northwestern Railway Beginning on Salado creek at Florence, and on Berry's creek south of Florence, the conditions are suited for flowing wells along their valleys to the Lampasas and San Gabriel rivers. Wells of small flow may be obtained in the valley of Brushy creek for nearly ten miles above Round Rock. In the valley of Brushy creek near Round Rock, San Gabriel river near Georgetown, and Berry's and Salado creeks north of

Georgetown, weak flows of water may be expected from wells at from three hundred to one hundred feet depths. In these cases the supply will be small, and the quality of the water probably poor and bitter from the presence of salts of magnesia, soda, strontia, etc., in solution, and sulphurous gases. Rarely this water may be valuable for medicinal purposes. The source of this supply is in the upper sandy stratum of the Glen Rose (Alternating) bed, which contains quantities of sulphate of magnesia, sulphate of strontium, and probably salts of soda. Upon the surface these minerals show in well defined crystals in the bluffs of Mount Bonnell, on the Colorado river, in Travis county, and in the bluffs along Rocky creek, in Burnet county.

Immediately west of the line drawn through Round Rock, Georgetown, Corn Hill, and Salado, which is approximately upon the line of the Balcones fault, water may be made to flow from wells at depths of from six hundred to eight hundred feet, while immediately east of this line it will be required to bore nearly one thousand feet at Round Rock, about seven hundred and fifty feet at Georgetown, and less than the latter amount at Corn Hill and Salado.

East of the Balcones fault line artesian water may be obtained with tolerable certainity, but there may be instances where a flow cannot be gotten on account of a thinning of the porous sand and conglomerate of the Trinity bed, in southern Lampasas county, resulting from a ridge-like elevation of Paleozoic rocks beneath Cretaceous strata.

Southeastward from the Balcones fault line, depths to which wells will have to be bored to obtain flowing water increases on an average of nearly one hundred feet per mile linear distance. Of necessity, differences in surface elevation affect the depths. Less will be required in the valleys than upon the adjoining hills.

ARTESIAN BASINS IN OTHER AREAS THAN LAMPASAS, BURNET, AND WILLIAMSON COUNTIES.

Within the limits of the rocks of the Bosque division in Hamilton, Erath, Bosque, Somervell, Hood, and Parker counties, there are artesian basins of limited extent, wherein an abundant supply of excellent flowing water may be had at very moderate depths. In some of them, for instance, that in the valley of the Paluxy creek, in Hood and Somervell counties, beautiful flowing wells are had at depths of from seventy to two hundred feet. In the vicinity of Glen Rose the flow from these wells is very abundant, being amply sufficient for irrigating gardens and small fields.

LEON RIVER ARTESIAN BASIN.

The exact limits in which flowing wells may be obtained in this basin have not been located, but it is known that conditions are suitable along the valley of Leon river from the Hamilton and Comanche county line

southeastward. Near the upper end it is probable that water may be obtained at depths of nearly one hundred feet. As the valley of the river is descended, it will require an additional depth of about fifteen feet for each mile's distance down the valley to reach the source of water supply. In the valleys of the small streams tributary to the Leon river in Hamilton county conditions are suitable to a distance of two to six miles from the river valley.

The basin continues down the Leon river valley through Coryell county, becoming wider as the valley descends, until it joins the great artesian area of the Cretaceous system in Central Texas. Cow House creek valley, below Pidcock ranch, presents conditions suited to flowings wells.

BOSQUE RIVER ARTESIAN BASIN.

The valley of the Bosque river, from Stephenville downward, Green's creek valley eastward and southeast of Dublin, Duffau creek valley near its mouth, and East Bosque river below the Houston and Texas Central Railway, form an artesian well basin, or valley, that has been scarcely appreciated. A beautiful flowing well at Iredell, three hundred and seventy-five feet deep, illustrates the possibility in this basin. The Bosque Section, Plate XI, shows the artesian conditions and source of supply for this valley.

Below the point on the Bosque river where the Paluxy sand bed, which borders the side of the valley opposite Walnut, reaches the base of the valley, flowing wells may be obtained at shallower depths. The source of the water is in the Paluxy sand. The flow will not be very strong, but if the boring is continued through the Paluxy sand and through the Glen Rose limestone below, an abundant supply will spring from the Trinity sand, from which source comes the water in the well at Iredell.

BRAZOS AND PALUXY BASINS.

Flowing wells may be drilled along the Brazos, beginning east of Comanche Peak, if localities be confined to the immediate valleys of the river. This basin joins the Paluxy basin at the mouth of Paluxy creek. At any point in the valley of Paluxy creek below Bluff Dale on Squaw creek near its mouth, and in the valley of the Brazos river between a point east of Comanche Peak and the south line of Somervell county, it will not be necessary to drill more than three hundred feet to secure a flow of water, and few wells will require to be drilled more than two hundred feet.

It will require a depth of nearly four hundred feet at the mouth of Camp creek on the Brazos river, in Johnson county, and between the mouth of Camp creek and the crossing of the Gulf, Colorado and Santa Fe Railway on the Brazos river, four to five hundred feet drilling will be necessary to get flowing water. Below the Gulf, Colorado and Santa Fe Railway, along the valley of the river, wells will flow at depths of

from one to two hundred feet. The source of this supply is found in the Paluxy sand bed, which passes beneath the surface of the river valley near the mouth of little Camp creek in northwest Hill county.

CLEAR FORK TRINITY RIVER ARTESIAN BASIN.

The valleys of Clear Fork of Trinity river, east of Weatherford, and the South Fork, below Weatherford, form a basin or area in which shallow flowing wells may be bored. In this area, as far southeast as Benbrook station, the source of the flowing water is in the Trinity sand, and the depths required for wells will be from one hundred to one hundred and fifty feet. Below Benbrook, in the valley of the river, wells must be from one hundred feet and upward according to locality and distance down the valley. The source of this is in the Paluxy sand bed. If the flow be weak, or if the water should rise to within a few feet of the surface, an additional depth of one hundred and fifty to two hundred feet will produce an abundant supply of flowing water from the Trinity sand bed.

There is another small artesian basin in north Parker county—the valley of Walnut creek from Springtown to the mouth of the creek. In Springtown, wells drilled to depths less than one hundred feet give a weak flow of water. Below Springtown it will require greater depth of drilling, but a stronger flow of water will be secured thereby. Investigations and estimates for flowing wells in these valleys have been made by the Survey, and since a living and excellent supply of fresh water is found that is within the reach of even the humblest farmer, it was considered expedient to give here some of the facts obtained.

ESTIMATES FOR ARTESIAN WELLS AT HONEY GROVE, PARIS, AND OTHER POINTS ON THE GULF, COLORADO AND SANTA FE AND TEXAS AND PACIFIC RAILWAYS IN LAMAR AND FANNIN COUNTIES.

In order to ascertain the character of the water-bearing sand for the artesian area in this part of the State, as well as to make reliable estimates of the depths to which artesian wells must be bored, it was necessary to go into the Choctaw Nation as far north as Antlers, on the St. Louis and San Francisco Railroad, and work southward in the direction of the dip of the rocks to the belt on which it is proposed to locate the wells. The sand which is the source of the artesian water is found exposed along the "Frisco" Railway from near Antlers to a point one and one-third miles north of Goodland, where it disappears beneath a bed of massive limestone, (Goodland limestone).

The sand is similar in general character to that of the same belt (Trinity and Paluxy sand) which extends along the eastern border of the Upper Cross Timbers in Texas. It is a porous, closely compressed, but not compact, white to yellow ferruginous sand. It is false-bedded and laminated. Contemporaneous deposition, erosion and redeposition

was so extensive at the time of its formation that reliable estimates cannot be made for the dips of the rocks.

There were occasional local ferruginous indurations of the sands, but these are not of sufficient extent to affect its water-bearing capacity. Between the upper limit of the sand, one and one-fouth miles north of Goodland, and a point nearly three miles south of that place, the whole of the Lower Cretaceous limestone series is exposed; and it was from these limestones that the only reliable estimates were obtained for the artesian water area under consideration.

Excellent exposures occur along the "Frisco" Railway across the prairie, north and south of Goodland, from which the average dip of the rocks was estimated.

TWO METHODS OF ESTIMATING DIP.

FIRST METHOD.—The longest possible exposures are selected parallel with the dip, which is here practically south. Such exposures were found from one hundred and sixty feet to one-fourth mile in length. The highest point on a ledge is selected, and here the observer places a level, and leveling carefully, sights to a point above the same ledge in the direction of the dip. The horizontal distance from the eye of the observer to the second point selected is measured; also the distance from the latter point downward to the level of the ledge of rock. The second or vertical distance is the amount of dip of the rock for the distance measured.

By this method dips were measured from the Goodland limestone at the base to the *Quadriplicata* bed at the top of the series. The average of all the dips measured, which ranged from 3.2 feet per one hundred feet distance to less than one foot per one hundred feet, was nearly one foot per one hundred feet distance, or practically fifty feet per mile.

SECOND METHOD.—A well drilled near Goodland, nearly one and one-third miles south of the southern limit of the sand, passes through the limestone at a depth of one hundred and sixty-eight feet and penetrated the sand. Water rose in this well sixty-eight feet, or practically to a level of the upper limit of the sand. Dip 50.8 feet per mile.

Paris is nearly twenty-eight miles due south of the point where the upper limit of the water-bearing sand crops out in the Choctaw Nation near Goodland, and the public square is nearly one hundred feet above this point of the sand. Estimating the dip of the rock from the sand north of Goodland to Paris at fifty feet per mile, in the twenty-eight miles the rock would dip fourteen hundred feet (28x50 feet equals 1400 feet), and adding to this the hundred feet (the elevation of Paris above the outcrop of the sand), the sum is fifteen hundred feet, which is the estimated distance of the water-bearing sand beneath the public square in Paris. The lowest elevation of the upper limit of the water-bearing sand, on Red River northwest of Denison, is nearly the same elevation

as Paris, and the elevation of the upper limit of the same sand, due west of Paris, is nearly eleven hundred feet.

After considering the above data, it seems impossible to determine whether water will rise to the surface at Paris when the water-bearing sand is penetrated. Theoretically, the water will not rise above the elevation of its source in the direction from which the rocks dip; but in this case, where the well is located in an artesian basin having two sides, with rocks dipping from two or more directions, and with sources both above and below the top of the well, it is probable that there will be a flow.

ESTIMATED DEPTH OF WATER AT HONEY GROVE.

The base of the Austin limestone, with its two hundred and eighty-five feet beneath the surface at Honey Grove, occurs at the surface nearly four miles south of Paris. Taking the grade of the country south of Paris into consideration, it is estimated that there is not more than one hundred feet from the rock on which Paris rests, vertically upward, to the base of the Austin limestone. The dip of the marl and sand in the vicinity of Paris could not be satisfactorily estimated.

Depth in rock from Paris downward to water sand	1500 feet.
Distance from Paris upward to base of Austin limestone	100 feet.
Base of Austin limestone to Honey Grove	285 feet.
Depth from surface at Honey Grove to water sand, estimated	1885 feet.

Honey Grove is ninety-six feet in elevation, by railway levels, above Paris; hence it is less probable that water will flow at the surface from a well at Honey Grove than at Paris.

By considering their distances and direction from and elevation above Paris, approximate estimates may be made for other localities in this vicinity.

SOILS.

The remarkable fertility of the Cretaceous soils of Texas, especially those of the black waxy lands of the Upper Cretaceous, has long been reputed. In the investigation of these soils it is the object of the Survey to (1) outline them as governed by the geological conditions of the rocks from which they take their source, (2) to note their physical characteristics, (3) to observe their natural and cultivated products, (4) and to analyze them chemically and physically in order to ascertain their adaptability to special crops.

Methods of Investigation.—The different divisions of the Upper and Lower Cretaceous series are so clearly marked, stratigraphically and lithologically, that it is an easy matter to divide and outline the several phases of the soil by simple geological delineations. As the geological field work is carried on the partings between these divisions, as well as between their subdivisions, are located and mapped, after which the soil study and detailed geological studies may be carried on rapidly and with little hindrance.

In this region, where unbroken virgin soils remain everywhere side by side with cultivated fields, the opportunities for the study of the physical properties of soils is unsurpassed. The natural selection of particular kinds of soils on the part of certain species of trees and herbaceous plants may be observed side by side with the behavior of the same soil under cultivation where fertilizers are unknown, and where the history of each field can be gathered from the farmer.

It is a matter of much importance to select good soil specimens. As stated above, the divisions of each class or phase of soils are so clearly marked that it is an easy matter to select specimens representing typically areas of many hundred square miles in extent. For instance, in the case of the Arietina clay, or Eagle Ford shale, a series of well-selected specimens from one locality will represent the same soil for one hundred miles along the strike of the rock. There is practically no change in the residual soils along any one of the beds of the Cretaceous system north of the Colorado river for more than one hundred miles.

In selecting a specimen for analysis a typical locality upon the bed is chosen, upon an extended level surface, where the soil has not been broken. The surface vegetation is removed, and the soil is selected with the subsoil where it is possible.

CHEMICAL ANALYSIS OF SOILS AND THEIR VALUES.—It goes without saying that the average farmer will derive but little benefit from a column of figures with unintelligible names, which, summing up one hundred, expresses the chemical analysis of a soil. If the physical characteristics of the soils are explained, such as the character of the rocks from which it has been derived, its color, its tendency to favor certain kinds of trees and herbaceous plants, and its drainage; and it is made clear in explanation that each plant that grows requires certain ingredients whose relative amounts in the soil are expressed by a percentage opposite their names in the column of analysis, the value of systematic analytic investigations of soils becomes evident.

SOILS OF THE TRINITY SANDS.

Naturally, one does not expect a very fertile soil which has an origin in a slightly calcareous and argillaceous sandstone alone. Such is the character of an unaltered purely Trinity soil. It is a loose pulverulent sandy soil, whose base or subsoil is a porous fine sand. This is rather the extreme case, however, for in many localities there is a sufficiency of clay to give body to the soil and to form an intermediate sandy clay soil as a transition between the soil and subsoil. This occurs often when there is a gentle slope, and when the soil rests blanket-like over the edges of various strata. In such cases the soil with its intermediate subsoil remains unchanged for a considerable distance, showing that its included clay does not have its origin in a single layer of rock. This phenomenon seems tenable only by the following explanation:

During a long period of time, as erosion slowly progressed in the forest-clothed sandy land, the compacted porous sand gradually disintegrates into a transition soil, and finally, after being acted upon by the elements and vegetable growth, it becomes the residual soil. Meanwhile, the particles of clay near the surface, and constitutent in the soil, are taken up in solution and suspension by the water that falls and passes down through the soils and rock and is left in the subsoil above the unchanged rock. By this process the surface soil is kept depleted of its store of clay, and in some localities where there is little clay on the country rocks the soil is little more than a deep loose sand, unfit for any use except to produce a scrubby forest-growth of oaks. The soil of the valley land is very fertile. Especially is this true of the river bottom lands. The rich silt deposited from the former floods of the river, combined with a good percentage of sand and clay brought down by the tributaries to the rivers from the Trinity sand, forms a soil of almost unsurpassed fertility. The large percentages of lime which must be present in these valley soils has its source in the rich lime marls of the Alternating and the Texana oyster beds which overly the sand, and in which quite all the smaller streams that flow in the Trinity sands have their source. The soil analyses Nos. 1 and 2 show excellent percentages of phosphoric acid, potash and lime.

Except in the valley lands, or where the surface is quite level and the drainage is slow, it is not profitable to cultivate the Trinity soil. Without exception the Trinity sand is forest covered. Many varieties of oak, also hickory and other hard woods abound upon the high or rolling land. The valley lands bear pecan, elm, dogwood, burroak, walnut, ash, hackberry, sycamore, willow, cottonwood, besides a luxuriant large grape, and varieties of thorn.

The wood of the Upper Cross Timbers (the eastern portion of which occupy the Trinity sand) is more valuable than the cultivated products of the rolling lands.

As soon as the timber is removed from the rolling sandy land, and the surface is broken by the plow, erosion rapidly removes the loose sandy soil, and the land becomes unfit for occupation even by the forest.

It may be said that at present there is no ready sale for the wood nor immediate use for it by the farmer who owns the land, but there are growing demands for the timber in the vast prairie regions east and west of these forest lands.

The soil upon the Trinity sand belt in Lampasas and Burnet counties is of no value for tillage. The area is narrow and generally occupies steeply sloping hillsides, and in consequence the soil is thin and porous.

THE GLEN ROSE (ALTERNATING) LIMESTONE SOILS.

The Alternating limestone and soft arenaceous lime marl of this bed form rich dark brown soils, but the character of the topography of the area occupied by these rocks will admit of only very limited land sur-

face where it is possible for residual soils of any value to form. As a rule the surface is abruptly rolling and partially occupied by a thin imperfect soil, fit only for pasture. The valleys of the streams, which have their source in and flow across these rocks, bear a very fertile dark brown soil, which have their origin solely in these lime-marls.

Soil and subsoil analysis (No. 1) from the Davis farm on South Rocky creek, in Burnet county, shows the percentage constituents of an average perfect Glen Rose limestone soil. The specimen was taken from an undisturbed level surface at the edge of the creek basin above overflow limits.

The same character of soils in the valleys will produce in good season from three-fourths of a bale to one bale of cotton, or forty to fifty bushels of corn, when properly cultivated. This soil is admirably suited to the production of peaches and grapes. Wild grapes grow luxuriantly in these valleys, a fact which shows conclusively that cultivated varieties of grapes will produce abundantly under skilled culture.

The percentage of lime, sand, clay and potash, as shown by the analyses, (see table of analyses) are excellent, with a fair per cent of phosphoric acid, which show proper proportions for a very fertile soil. The bases of the valleys and hillsides adjoining the principal streams are clothed with growths of pecan, oak, hackbery, elm and other hard woods indigenous to this region. Many of the pecan groves are preserved and are a source of considerable profit to owners. Single trees and clumps of liveoaks are scattered here and there over the hills, giving picturesque and pleasing views to the landscape. Varieties of dwarf-oak are encroaching upon the hills also, since prairie fires have been stopped, and since close pasturing in many places has depleted the soil of its sod, thereby giving the acorn and herb seed a chance to take root.

THE TEXANA AND COMANCHE PEAK LIMESTONE SOILS.

Generally the residual soil derived from the Comanche Peak and Texana limestones is thin and imperfect, and consequently poor. The edges of these exposed beds in a great measure occupy escarpment faces and sloping hillsides, hence their lack of well formed residual soils. Rarely these rocks occupy the summits of divides between river or creek valleys, where rich black residual soils occur, which produce abundant crops of corn and cotton and fine pasture lands. Such a divide is that between the San Gabriel river and Rocky creek in Burnet, and between the Russell Fork and North Fork of the San Gabriel river in Williamson county. At these localities the harder Caprina limestone with flints, which generally form table lands above the Texana and Comanche Peak beds, have been removed, leaving the bottom beds with gently rolling surfaces.

These soils have an abundant supply of lime and a good percentage

of potash and phosphoric acid, as shown in analysis No. 2 in table of soil analyses. Quite a good percentage of clay is seen to be in this soil also.

The soil specimen of analysis No. 2 was taken from the Texana bed, upon high gently rolling country, two miles northwest of Gabriel Mills, in Burnet county. The soil is very dark brown and residual upon the unbroken prairie. The soil of the Comanche Peak limestone will contain less percentages of clay and more of lime than that of the Texana limestone.

THE CAPRINA LIMESTONE SOIL.

A belt of country formed by this rock passes north and south across Williamson county west of Round Rock and Georgetown, and extends northwest upon the divide between the principal stream valleys. It is covered by quite a dense forest of oaks, hickory and cedar, and by many fragments of indurated Caprina limestone and flint bowlder nodules. Upon extended level surfaces and shallow valleys there is a brown to reddish brown residual soil of highly productive fertility, but it is rarely free of limestone and flint fragments. Soil of analysis No. 3 was selected from a level unbroken surface of Caprina soil two miles northwest of Georgetown. Potash and phosphoric acid percentages are not high, but they seem to be rendered quite active in their productive power by suitable percentages of lime, clay, iron and finely diffused siliceous matter in the soil.

The area of the soil is more valuable for forest land than for agricultural uses. The habit of clearing the cedar forests promiscuously for firewood is to be deprecated. Its value for building timber and fence posts is beyond that for fuel, and its value in this respect will continue to increase with increase of population in the adjoining prairie region.

THE FORT WORTH LIMESTONE SOIL.

The Fort Worth limestone occupies a very limited area in Williamson county on account of the disturbances incident to the Balcones fault, which have almost concealed the one hundred and fifty feet of strata. The soil upon the areal expanse of this rock is of little importance in an agricultural sense. It is quite thin and imperfect, with much limestone fragments on the surface.

The timber belt of the Caprina bed continues upon the soil of the Fort Worth limestone, but the forest here is not so dense, being relieved here and there by patches of prairie land.

THE SOIL OF THE ARIETINA CLAYS.

With rare exceptions does the soil of the Arietina clay occur upon level surfaces. This clay is in part involved in the Balcones fault. It is of sufficient thickness to give an areal width of one or more miles, but on account of the overlying hard Vola limestone its width is rarely

more than one-fourth of a mile. It is rarely cultivated on account of its sloping surface and imperfectly formed soils.

SOILS OF THE UPPER CRETACEOUS.

The soils of the Eagle Ford shales, Austin limestone, and Blue marl in Williamson county present the same surface features. The pure soils are of a dense black color, running high in percentages of lime and clay. Chemical analysis of the specimens of soils selected does not show high percentages of potash or phosphoric acid. The high percentages of lime and iron which are always present in the Eagle Ford shales and Blue marl most probably renders active the potash and phosphoric acid ingredients. The highly productive quality of these soils is rendered possible only by its physical conditions and its high water absorptive and retentive power.

The country rock of the Eagle Ford shale and Blue marl contains fair proportions of potash and phosphoric acid ingredients, and the soil may be improved by deep plowing or any other process of mechanical mixture of the subsoil and the country rocks. The shale and marl is friable, and "slacks" immediately upon surface exposure. The whole areal exposure of these rocks is occupied by a gently rolling prairie land, and almost every acre is subject to cultivation.

DRIFT SOILS.

All of the area of the Upper Cretaceous in Williamson county is occupied by drift soil, except narrow borders of land along the edge of the creek basins and a few square miles possibly upon the top of the divide between the San Gabriel river and Brushy creek. This soil is residual, and has its origin in the mingled rock debris from both the Lower and Upper Cretaceous. In the greater portion of this area the soil originates solely from the drift, and there is a body of drift yet remaining unchanged beneath the soils often to a depth of several feet. Over the larger portion of this area the subsoil is Eagle Ford shale, Austin limestone or Blue marl. A thin mantle of drift, in the form of pebbles of flint and worn Lower Cretaceous limestone, remains upon the surface and lends character to the soil.

As a rule these soils prove to be very fertile. Their surface is gently rolling and often inseparable by surface appearances from the purely marl soil. Upon extended level surfaces "hog-wallows" occur as upon the Eagle Ford shale and Blue marl. Except upon the banks of the creeks and bases of small valleys the whole area is an open prairie. The soils of the river and creek valleys, though of limited extent, are exceedingly fertile. They result from decomposition of Cretaceous rocks of the whole system, and are highly humus charged. The valleys of the large streams bear rich growths of ash, oaks, pecans, elm, hackberry, sycamore, wild grape, and other woods indigenous to this region.

ANALYSES OF SOILS.

CHEMICAL ANALYSIS.

	1.		2.		3.		4.	5.	6.	7.
	Soil.	Sub-soil.	Soil.	Sub-soil.	Soil.	Sub-soil.				
Insol. in hydr. acid	56.94	49.02	66.08	5.00	63.52	54.52	63.80	57.03	67.67	80.94
Soluble silica	0.12	. .	. .	. .	1.05	0.227	0.17	0.20	1.38	0.204
Ferric oxide	2.29	3.06	1.35	3.10	4.89	4.54	4.66	5.21	3.33	1.92
Alumina	4.81	7.89	9.65	trace	9.99	9.14	8.99	10.52	3.18	2.78
Lime	14.66	18.16	3.16	50.00	1.83	9.85	2.08	3.78	8.81	1.92
Magnesia	trace	1.73	0.50	trace	0.37	0.115	0.58	0.32	. .	0.31
Soda	3.99	4.31	3.92	4.30	0.95	1.42	0.50	1.06	0.14	0.20
Potash	1.43	1.43	1.91	0.57	0.35	0.16	0.51	0.65	0.38	0.23
Phosphoric acid	0.10	0.05	0.09	0.06	0.055	0.094	0.53	0.033	0.049	0.072
Sulphuric acid	0.42	0.24	0.33	0.49	0.12	0.077	0.15	0.13	0.14	0.11
Carbonic acid	11.51	14.27	2.50	36.29	1.20	5.57	1.57	2.73	4.31	0.81
Water	2.64	trace	0.94	0.29	5.35	3.62	3.89	5.64	3.29	2.26
Organic matter	1.00	trace	9.36	trace	. . .	. . .	. . .	. . .	. . .	. . .
Loss on ignition	. . .	. . .	. . .	. . .	10.60	11.72	12.81	12.99	8.86	7.89

MECHANICAL ANALYSIS.

	1.	2.	3.	4.	5.	6.
Stones	. . .	. . .	9.80	6.53	13.74	8.46
Coarse gravel	. . .	. . .	11.44	19.27	26.00	7.92
Gravel	44.00	70.00	28.30	8.08	14.90	8.34
Coarse sand	. . .	. . .	3.74	4.06	3.14	4.14
Find sand	12.00	10.00	3.32	7.35	2.66	5.32
Silt	44.00	20.00	43.40	53.71	39.56	65.98

LOCALITIES.

1. Davis farm on South Rocky creek, Burnet county. Soil from creek valley, having origin in the Glen Rose limestone.

2. Two miles northwest of Gabriel Mills, Burnet county. Residual soil from limestone of Texana bed.

3. Two miles northwest of Georgetown, Williamson county. Residual soil from Caprina limestone.

4. Two miles east of Georgetown. Residual soil from Arietina clay.

5. Three miles east of Georgetown. Residual soil from Eagle Ford shale.

6. Four miles southeast of Thorndale, Williamson county. Soil from Ponderosa marl.

7. North of Thorndale. Soil from drift.

TRANS-PECOS TEXAS.

BY

W. H. VON STREERUWITZ.

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The country west of the Pecos river, at least west of the divide running from the Guadalupe mountains down to the Rio Grande and crossing into Mexico, is sharply distinct from the country east of the Pecos river, for although we find in the Central Region (Llano and surrounding counties) granites, crystalline schists, Silurian and Carboniferous rocks, metamorphic material and perhaps Devonian strata, alike or similar to those of Trans-Pecos Texas, here we have to deal with geological problems of a different and far more complicated character. Some, I dare say most, of these problems can and will be understood fully only after the mountains of Old and New Mexico have been studied more in detail, because the chronology and sequence even of local events can be ascertained and understood only by comparing all or most of the features of these localities with each other.

As far as the eruptive material is concerned we have evidently to deal with the same material found in Old and New Mexico, thrown up probably at the same time, under the same or similar conditions, and partly, at least so far as the southwestern portion of New Mexico is concerned, penetrating the same sedimentary strata. After the Carboniferous sea had subsided the country evidently remained a plateau region of large extent. Numerous buttes, peaks or high hills, more or less connected with each other, of the same character and bearing the same fossils, still remain stretching from the flanks of the Sierra Diablo to Sanderson, forming quite extensive mountain ranges similar to the Sierra Diablo, flanking eruptive ranges and mountain groups such as the Hueco and Carrizo mountains, and forming extensions of mountain ranges, like the southern parts of the Guadalupe and Van Horn mountains. The northern boundary of this plateau was, if not considerably further north, certainly not south of New Mexico. As to the eastern and southern boundaries, I think the Pecos river may be assumed for the former, and the western limits we have to look for in Mexico. How far west cannot be even approximately guessed from observations made up to date. In short, from the fragmentary work done in Texas, New and Old Mexico up to this time, it is impossible to determine sharply and distinctly the limits of this once extensive plateau, the existence of which cannot be doubted. The present remains of it terminate on the east side of the Sierro Diablo in high cliffs overlooking a broad valley or basin, the eastern shore of which was formed by equally high and steep cliffs, which form the southern extension of the Guadalupe mountains, sloping down towards the Pecos river.

Similarly abrupt cliffs flank the Hueco and Wiley mountains, and we meet them along the Galveston, Harrisburg and San Antonio Railroad where they extend toward the river and into the interior of Trans-Pecos Texas. These cliffs, though of the same period, are not all of the same horizon, and they border everywhere large flats or basins between the eruptive mountains. These basins or flats are all connected, and some of them are again subdivided into smaller basins by cliffy Cretaceous ranges.

There is a remarkable uniformity of character in the material of the respective sedimentary formations and in their arrangement; but while the dip of the Carboniferous strata is mostly very slight, frequently practically horizontal, the inclination of the Cretaceous is, with few exceptions, considerably steeper, and the extent of the visibly remaining Cretaceous hills or mountain ranges in the western part of Trans-Pecos Texas is small compared with the Cretaceous formations along the eastern slope of the divide toward the Pecos river, which country has been regarded as entirely Cretaceous, but it may be safely predicted that closer examinations will also show remnants of the Carboniferous plateau.

Up to this time I have found no Tertiary deposits in those parts of Trans-Pecos Texas which I have had opportunity to examine, and I think it is not possible they can exist, in view of the denudations which evidently took place, since not only were the Cretaceous strata destroyed, but the erosion cut down even to the Devonian.

The stratigraphic character of the basins or valleys downwards from the recent surface covering to the bottom cannot even be guessed. True there are a number of wells bored along the Galveston, Harrisburg and San Antonio and the Texas and Pacific Railroads, but no records have been kept of the strata penetrated in the borings. I ascertained that the material at ten hundred and fifty feet in the well at Torbert is seemingly the same as that a few feet under the grass-roots—loose gravel and sand, never touching solid rock.

These large valleys or basins separating the single mountain ranges and mountain groups, cover and obliterate from vision all connections, contacts and transitions, and are one of the greatest obstacles to the ready understanding of the geological features of the country. What is seemingly the foot of the mountain is in fact the upper part, and the foot is buried under several thousand feet of the debris of the strata from the Devonian up to the most recent period.

The mountains between the longitudes 105 degrees and 104 degrees 55 minutes west of Greenwich, lying between parallel 30:55 north latitude and the continuous high limestone cliffs about eight miles north of the Texas and Pacific Railroad, are generally called the Sierra Carrizo, and the mountain range extending north from the cliffs toward and partly alongside of the Salt Lake valley, and terminating at the

Sierra Prieta, are known as the Sierra Diablo. This is here accepted as a correct definition of the two ranges.

After quitting the topographical work last summer, when the topographers of the United States Geological Survey resumed this task, I began with a closer examination of the Carrizo mountains, and found their southern part (south of the Galveston, Harrisburg and San Antonio Railroad) to consist in their entirety of crystalline schists of Archæan age, tilted by and resting on a reddish granitic eruptive rock, and flanked by Carboniferous limestones and Cretaceous (?) sandstone. The schists are not yet determined petrographically, but judging from their appearance they are micaceous, together with talcose clay, slates and siliceous schists. Very large strongly ferruginous quartz leads can be traced through this whole mountain group, of uniform character with those appearing in the Van Horn mountains, about twelve miles distant.

The cliffs of the Sierra Diablo are built up of marine Carboniferous limestones, which in their upper part rise in most places nearly perpendicularly to a height of about two hundred feet above the steep sloping detrital cone, which in many places, particularly on the north side, is indurated to a solid breccia. This gives the impression of a stratum of breccia existing between the limestone. Closer examination proves, however, that this cannot be the case, since this breccia consists entirely of fragments of superimposed strata, and besides can nowhere be found on the other side of the mountains. This Carboniferous limestone rests, as far as exposed surfaces show, conformably on finer or coarser red grit, which, alternating with coarse conglomerates in some places, is exposed to the height of three hundred feet, and which judging from its character and stratigraphic position, is of Devonian age.

These grit beds thin out south toward the Texas and Pacific Railroad, and are there superimposed unconformably on the crystalline schists of the Sierra Carrizo, a transition breccia of about one foot intervening between the schists and the grits. The cliff along the Texas and Pacific, about five miles west of Van Horn, is the only place where I have yet found this sequence of strata exposed, but the unconformity of character of the upper strata, partly exposed down to and into the Devonian, justified the conclusion that the crystalline schists underlie the whole Diablo mountains, and probably extend also under the cliffs bordering the east side of the basin flat north of Van Horn, up to the Guadalupe mountains.

Between the cliffs along the railroad and the most southern cliff of the Sierra Diablo proper, about eight miles north of the railroad, the red grits extend, denuded of the Carboniferous limestone, and form grotesque cliffs and small plateaus, and fine-grained red sandstone in gently sloping hills, some of which are covered with thin limestone strata.

The western part of the mountain range, between the Texas and

Pacific and the Sierra Diablo cliffs, on the road from Allamore toward the Hazel mine, consists of cherty metamorphic limestone mountains with intervening strata of crystalline schists and greenstone and basaltic dykes. East of this road the mountains are composed of a breccia of metamorphic Carboniferous limestone with occasional pieces of the red sandstone in a hard, mostly ferruginous limy cement. West of Carrizo station the front cliffs are obliterated, leaving only gently sloping Carboniferous limestone hills.

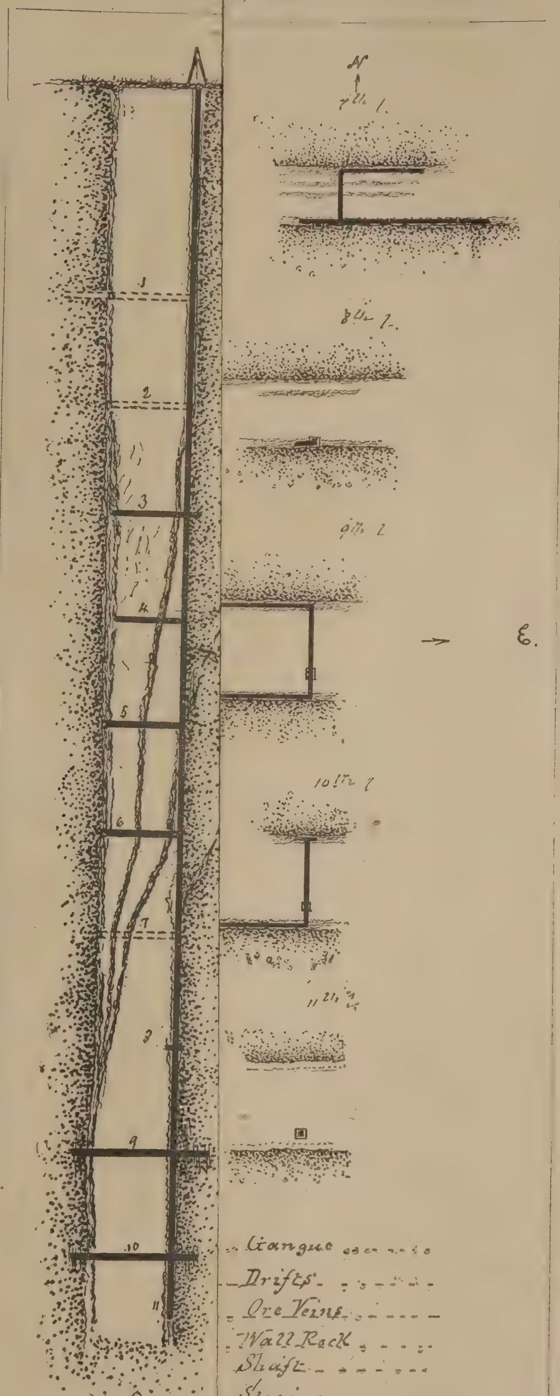
The cliffs appear again at Eagle Flat, ten miles west of Allamore, running there for a distance of about one mile parallel with the Texas and Pacific, and terminating northwest in a number of partly obliterated mountains, also of Carboniferous age; and here, in and between the mountains, we meet again a range of brecciatic mountains, now and then visibly underlaid with the red grits of the Sierra Diablo.

On the south side of Eagle Flat cliffs I found in the ravines the outcropping of the Sierra Carrizo schists. The talus, however, covers the foot of the hill to such an extent that a contact between the schists and the Devonian cannot be positively proved, though there can be little doubt that the schists rest on the same or similar eruptive rocks as in the Carrizo mountains. The extension of the granitic and porphyritic rock up to Eagle Flat and further east, and its connection with those in New Mexico, cannot be doubted and will certainly be proved as soon as the observations can be extended to the Guadalupe mountains, the mountain groups north of the Sierra Diablo, and further west to the Hueco ranch and the Franklin range, the most southern part of the Organ mountains.

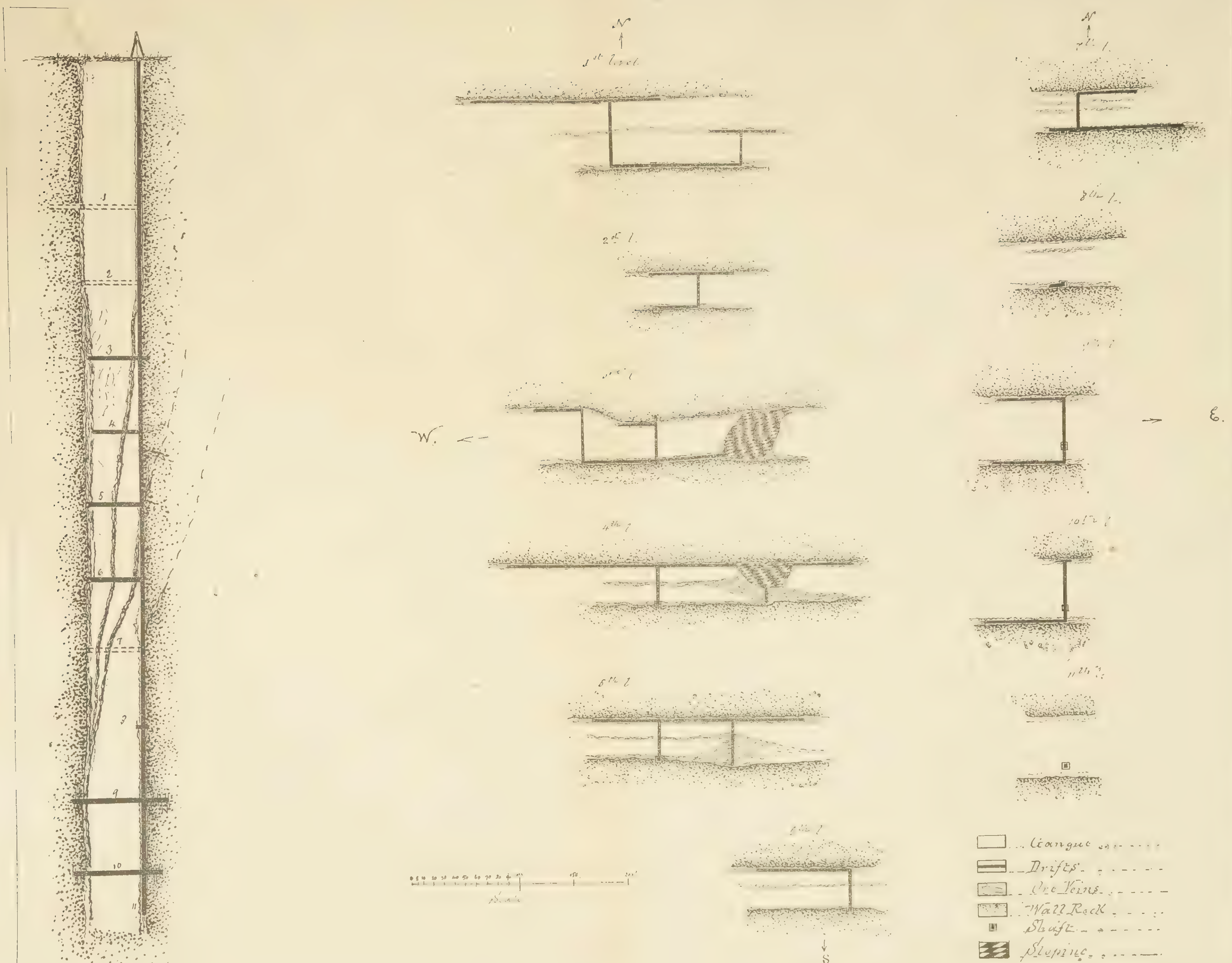
Fuller knowledge of the more northern portion of Trans-Pecos Texas and of New Mexico is missing up to date, and therefore it is difficult, or more correctly, it is impossible to correlate the plateau formation of West Texas with that of the Zuni plateau; but many of the characteristic features of the Zuni plateau, as described by Captain C. E. Dutton, seem to find their counterparts in Trans-Pecos Texas. Toward the east we have also to deal with Carboniferous plateaus and intervening large basins, and with strata covered with lava and trachytic rocks, though volcanic cones and the product of true volcanoes seem to be missing. The lavas, basalt and trachytes here are evidently the product of fissure eruptions of great extent, for we find the eruptive rock cappings from the Eagle and Van Horn mountains east through the Viejo and Chinatti mountains to and into the Apache group and its continuation towards the great bend in the Rio Grande.

We evidently have to deal in West Texas with the same forces active in the denudation, and we come to the conclusion that the mountains, as far as they are not the remnants of former high lands, were not elevated and pressed up by horizontal compression, but by the action of plutonic and volcanic forces.

GEOLOGICAL T, 1891. PLATE XVI.



VERTICAL SECT



VERTICAL SECTION. HORIZONTAL SECTIONS.

HAZEL MINE.

The absence, or perhaps only the scarcity, of visible contacts of the eruptive with the sedimentary horizons makes it impossible to express a well founded conclusion about the age of the eruptions, but it seems probable that we will have to call most of them Tertiary—hardly any older than Cretaceous.

Very little prospecting is done in the Carrizo mountain group, but even the little work done up to date justifies the expectation of excellent results from more extensive work. The shallow diggings of Uncle Jake's prospect, though not having yet struck the main lead, shows fine specimens of gray copper (Fahlerz,) which may be regarded as a silver ore. The surface material from an iron outcrop five miles west of Van Horn contains sulphate of lead crystals, and assayed in some specimens seventeen ounces of silver. It can hardly be doubted that this iron outcrop, which in the same hill runs parallel with other similar croppings, is only the iron capping (gossan) of a large silver-bearing lead and copper lead. A number of the older prospect holes near Bass's canyon show very promising ores on dump, and were abandoned before the wells at Van Horn station were finished, because it was nearly impossible to find even a scanty supply of water nearer than fifteen or twenty miles from the prospect.

As far as the ore-bearing character of the Sierra Diablo is concerned, I have to state that up to this time I have been able to examine only the part located between the Texas and Pacific Railroad and the cliffs eight miles north. The age and character of the mountains and a number of mostly shallow holes, some of them showing well defined leads with good material on dump, prove that this part of the country fully deserves to be ranged among the mineral districts of the State. I find full confirmation of what has been before said about their ores; and in this district we find, in spite of the drawbacks mentioned over and over in every one of my former reports, the well developed Hazel mine at the foot of the Sierra Diablo cliff.

This mine is owned by Messrs. Shriver & Andrews, of San Antonio, and is located about ten miles north of Allamore station on the Texas and Pacific Railroad. The gangue is nearly perpendicular. Its width to a depth of about five hundred feet averages thirty-four feet, below this depth it widens to over forty feet. Its longitudinal extension may be traced for several miles, and its nearly uniform thickness is ascertained for eighteen hundred feet by the present workings shown in the accompanying sketch. The gangue is in a fissure between a fine grained red sandstone of probable Devonian age, which also forms the walls, and which, in the vicinity of the gangue, is more or less metalliferous. The gangue has a whitish gray colored calcareous silicate, more or less impregnated through nearly its whole width with copper and silver sulphide and other metal combinations, and numerous richer

veinlets fill the space between the two principal veins known as the north and south veins.

The north vein runs from the outcrop to the whole depth reached at the time I made the examination (June, 1891,) down to five hundred and seventy-five feet practically perpendicularly. The south vein runs also perpendicularly to about one hundred and fifty feet, when it changes its dip slightly to the north and joins the north vein at about four hundred and fifty feet from the surface.

At about three hundred feet from the surface another vein was struck on the south side, which joins the north vein at about five hundred feet. A vein running in at three hundred and sixty feet through the south wall dips nearly parallel with the north vein to the full depth of the shaft, thus forming the south vein in the deeper parts of the mine. The strike of the gangue and the veins is nearly true east and west.

The east shaft, on which most of the work has been done, is sunk on the south vein, reaching (June, 1891,) the depth of five hundred and seventy-five feet. From this shaft every fifty feet crosscuts are made to the north vein, determining the average width of the gangue from wall to wall to be about thirty-five feet. From these crosscuts as well as directly from the shaft, more or less extensive drifts are run in the north and south veins, as shown by the acompanying sketch, and the quantity and quality of ore struck by shafting and drifting in the veins and in pockets is highly promising to actual mining by stoping.

The west shaft is sunk on the north vein, eighteen hundred feet west of the east shaft, to a depth of three hundred and seventy-five feet and about three hundred and fifty feet of crosscuts and drifts worked from this shaft.

The middle shaft is three hundred feet west from the east shaft, on the north vein. It is forty-two feet deep, and was last June a drift of about forty feet in a material of the same character as the east shaft. The walls, as well as the gangue material in all the shafts and drifts, are sound and solid, and therefore very little timbering is required. Up to the time I made an examination of this mine no obnoxious gases were noticed, except those resulting from the blasts, and very little water was struck in the shafts and drifts.

The principal ores of the main veins, as well as the veinlets and pockets, are silver-bearing copper glance, gray copper, silver copper glance, silver glance, native silver, chlorides with more or less copper. Lead, antimony and arsenites are found in traces, and traces of gold are not infrequent, and strongly ferruginous specimens assayed ninety-five hundredths of an ounce in gold and thirteen ounces in silver. The gray copper yields very high assays up to two thousand ounces in silver, and assays of some of the copper glance exceed six hundred ounces to the ton.

These as well as the other combinations mentioned above are deposited through the vein material (calc-silicates, frequently heavy spar) widening out occasionally to pockets of considerable size, and resulting in those ores which stand shipping without concentration.

The whole gangue between the east and west shaft may be regarded as filled in with low grade ore through which the richer veins, pockets and veinlets are dispersed, and I regard it anything but an exaggeration to estimate the value of the ores in this mine as far as it is opened for work at twenty million ounces of silver.

There is no doubt that the greater part of the material on dump, not rich enough to be shipped without concentration, is a low grade ore worth being worked by lixiviation.

The red sandstone, in which the gangue runs to the depth of five hundred and seventy-five feet, will probably change into a crystalline schist or granitic rock at greater depth, and this change will in all probability favorably influence the ore-bearing.

There are numerous outcrops and prospects in the Sierra Carrizo, up to the cliffs of the Sierra Diablo, just as promising as those of the Hazel mine were. The same can be said of the outcrops and prospects of the Quitman and Chinatti mountains. To develop them requires only capital, energy and experience, as proved by assays made in the laboratory of the Geological Survey.

INDEX.

C.

H.

M.

N.

O.

P.